PB82-265471

Historical Review of Water Quality and Climatic Data from Chesapeake Bay with Emphasis on Effects of Enrichment

Maryland Univ.
Solomons

Prepared for

Environmental Protection Agency
Annapolis, MD

Sep 82

U.S. Department of Commerce
National Technical Information Service
NTIS

PB82-265471

EPA 600/3-82-083
September 1982

Historical Review of Water Quality and Climatic Data from Chesapeake Bay with Emphasis on Effects of Enrichment

by

Donald R. Heinle[1]
Christopher F. D'Elia
Jay L. Taft[2]
John S. Wilson
Marthe Cole-Jones
Alice B. Caplins[3]
L. Eugene Cronin[4]

University of Maryland
Center for Environmental and Estuarine Studies
Chesapeake Biological Laboratory
Solomons, Maryland 20688

[1] Present Address: CH2M Hill, 1500 114th Avenue S.E., Bellevue, Washington 98004

[2] The Johns Hopkins University, Chesapeake Bay Institute, Baltimore, Maryland 21218

[3] Present Address: Sperry Univac Corporation, Route 4, Box 424V, Great Mills Road, Lexington Park, Maryland 20653

[4] Chesapeake Research Consortium, Inc., 1419 Forest Drive, Suite 207, Annapolis, Maryland 21403

Grant #R806189010

Project Officer

Thomas Pheiffer
U.S. Environmental Protection Agency
Chesapeake Bay Program
2083 West Street
Annapolis, Maryland 21401

Chesapeake Research Consortium, Inc. Publication No. 84.

1980

UMCEES Ref. No. 80-15CBL

REPRODUCED BY
NATIONAL TECHNICAL
INFORMATION SERVICE
U.S. DEPARTMENT OF COMMERCE
SPRINGFIELD, VA. 22161

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)

© U.S. GOVERNMENT PRINTING OFFICE 1980-660-630

TYPING GUIDE SHEET

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

1. REPORT NO.
EPA 600/3-82-083

2.

3. RECIPIENT'S ACCESSION NO.
PB82 265471

4. TITLE AND SUBTITLE
Historical Review of Water Quality & Climatic Data from Chesapeake Bay with Emphasis on Effects of Enrichment

5. REPORT DATE
September, 1982

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)
Donals R. Heinle, Christopher F. D'Elia, Jay L. Taft, John S. Wilson, Marthe Cole-Jones, Alice B. Caplins, L. Eugene Cronin

8. PERFORMING ORGANIZATION REPORT NO.
CBP-TR-002E

9. PERFORMING ORGANIZATION NAME AND ADDRESS
University of Maryland, Center for Environmental &
Estuarine Studies, Chesapeake Biological Laboratory,
Solomons, Maryland 20688

10. PROGRAM ELEMENT NO.

11. CONTRACT/GRANT NO.
R806189010

12. SPONSORING AGENCY NAME AND ADDRESS
EPA, Chesapeake Bay Program
2083 West Street
Annapolis, Md. 21401

13. TYPE OF REPORT AND PERIOD COVERED
Project Report

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Review of the available data on water quality in Chesapeake Bay has revealed changes over recent decades caused by enrichment with nutrients. In the upper and middle Bay, and several tributaries, concentrations of algae present during the summer months have increased since the mid 1960's. There have been decreases in the clarity of the water associated with increased algal stocks. Nutrient concentrations have also increased, phosphorus more notably so than nitrogen. In some of the tributaries, such as the Patuxent for which we have the most historically complete data, increased algal production has led to reduced concentrations of oxygen below the halocline in the middle part of the estuary. The variations in concentration of oxygen are now more extreme in surface waters than in the early 1960's in the Patuxent. Oxygen concentrations in the open Bay have not changed greatly with the possible exception of extreme conditions, as during periods of extensive ice cover. There have been historical variations in the abundance of commercial fishery stocks that are closely related to climatic variations. Since 1969 or 1980, however, stocks of many anadromous species and marine spawners representing higher trophic levels have declined to new long-time lows. The principal exceptions are menhaden (marine-spawning planktivorous fish) & bluefish (marine spawning top predators). That same time interval has, however, been a period of above average rainfall and corresponding reduced salinities in the Bay, making conclusions concerning effects of enrichment difficult to achieve.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
	Chesapeake Bay, Eutrophication	

18. DISTRIBUTION STATEMENT
Unrestricted distribution

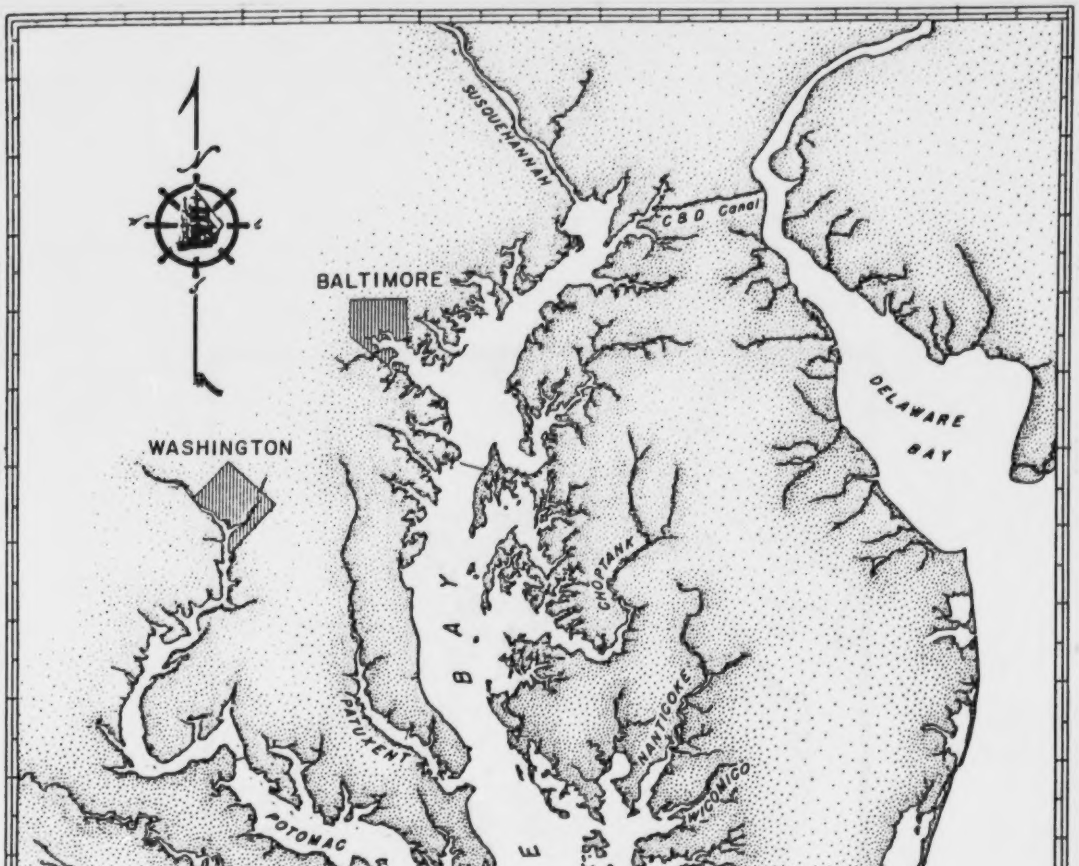
19. SECURITY CLASS *(This Report)*
Unclassified

20. SECURITY CLASS *(This page)*
Unclassified

21. NO. OF PAGES
242

22. PRICE

EPA Form 2220-1 (9-73)


SUSQUEHANNAH
C&D Canal
BALTIMORE
WASHINGTON
DELAWARE BAY
CHOPTANK
BAY
PATUXENT
NANTICOKE
WICOMICO
POTOMAC
CHESAPEAKE
RAPPAHANNOCK
RICHMOND
YORK
JAMES
ATLANTIC OCEAN
0 10 20 30 40
NAUTICAL MILES
NORFOLK

Frontispiece. The Chesapeake Bay and its major tributaries.

TABLE OF CONTENTS

Summary 1

Introduction 2

Chapter A, Climatic Variation 4

Chapter B, Nutrient Inputs 14
- Current Inputs 14
- Historical Trends 20
- Pesticides 26

Chapter C, Historical Changes in Water Quality 31
- Introduction 31
- Methods, Comparability, and Limits of Detection 32
  - Quality assurance and the historical data record 32
  - Analytical Methods 33
  - Chronology of colorimetric detection device use 38
- Upper Chesapeake Bay 38
- Middle Chesapeake Bay 45
- Lower Chesapeake Bay 56
- Choptank, Chester and Miles Rivers 58
- Magothy, Severn and South Rivers 61
- Patuxent River 62
- Potomac River 81
- James River 84
- Other Tributaries of the Bay 91
- Summary of Water Quality 93

Chapter D, Commercial Fishery Production 99

Chapter E, Current Status of Chesapeake Bay with Respect to Enrichment 109

References 115

Appendix A, Accessing Environmental Data Base Directory Climatic Data 129

Appendix B, Environmental Data Base Directory 132

Appendix C, Fisheries catch data documentation 221

Appendix D, Unpublished manuscript "Climatic Factors Influencing Commercial Seafood Landings in Maryland" by Ulanowicz, et al. 223

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

SUMMARY

Review of the available data on water quality in Chesapeake Bay has revealed changes over recent decades caused by enrichment with nutrients. In the upper and middle Bay, and several tributaries, concentrations of algae present during the summer months have increased since the mid 1960's. There have been decreases in the clarity of the water associated with increased algal stocks. Nutrient concentrations have also increased, phosphorus more notably so than nitrogen. In some of the tributaries, such as the Patuxent for which we have the most historically complete data, increased algal production has led to reduced concentrations of oxygen below the halocline in the middle part of the estuary. The variations in concentration of oxygen are now more extreme in surface waters than in the early 1960's in the Patuxent. Oxygen concentrations in the open Bay have not changed greatly, with the possible exception of extreme conditions, as during periods of extensive ice cover.

There have been historical variations in the abundance of commercial fishery stocks that are closely related to climatic variations. Since 1969 or 1970, however, stocks of many anadromous species and marine spawners representing higher trophic levels have declined to new long-time lows. The principal exceptions are menhaden (marine-spawning planktivorous fish) and bluefish (marine spawning top predators). That same time interval has, however, been a period of above average rainfall and corresponding reduced salinities in the Bay, making conclusions concerning effects of enrichment difficult to achieve.

There is evidence for progression of the effects of enrichment down the Bay with time. Increased inputs of nutrients may ultimately lead to major changes in the lower Bay, similar to those already observed in the tributaries and upper and middle Bay.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA: OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN EPA FORM 327)
☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-660-639
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

INTRODUCTION

There has been growing concern in recent years over the effects of excessive enrichment of coastal waters. That concern has led to at least three workshops at the national level (Glendening and Curl, 1978; Curl, et al., 1978; Goldberg, 1980) in which processes and effects of excessive enrichment have been discussed, and general research and monitoring needs have been recommended. Concern for effects of enrichment has not been restricted to the United States. Excessive enrichment is considered a threat to some parts of the Mediterranean Sea (United Nations Environment Programme, 1977) and several other coastal areas around the world (Curl, et al., 1978).

The first concerns about sewage enrichment in Chesapeake Bay noted in the literature focused on the health hazards of untreated or primary treated sewage (Cumming, 1916; Cumming, Purdy and Ritter, 1916). In the early 1900's outbreaks of typhoid fever were relatively common, often as a result of contact with, or drinking of, contaminated water, and sometimes from eating shellfish (Cumming, 1916; Cumming, et al. 1916). Nonetheless, the biological oxygen demand of untreated or partially treated sewage was recognized to decrease concentrations of oxygen in heavily polluted areas such as the upper Potomac River (Cumming, et al., 1916) and Baltimore Harbor (Cumming, 1916).

With the development of sewerage in urban areas and as the use of secondary treatment increased, it became apparent that the ultimate oxygen demand caused by decaying algae which bloomed as a result of increased nutrients in the water could be as great as the direct oxygen demand of untreated sewage (Wolman and Geyer, 1957; Jaworski, Lear and Villa, 1971, 1972). It has been estimated that the decomposition of the algae represented by a chlorophyll concentration of 100 ug l^{-1} would require about 12 mg l^{-1} of dissolved oxygen, varying somewhat depending on the amount of refractory organic matter (Bain, 1967; Jewell and McCarty, 1968).

Stimulated production of algae is often accompanied by other changes which are less direct. Changes in species composition may result. In waters of low salinity, nitrogen-fixing blue-green algae often become the most abundant forms, to the detriment of higher aquatic organisms and other algae. Blue-green algae also can produce conditions considered offensive to humans, such as fouled beaches and noxious odors. Blue-green algae were observed in the upper Potomac estuary as early as 1913 (Cummings, et al., 1916), but did not become a serious nusiance until the middle to late 1960's (Jaworski, et al., 1971, 1972). Problem quantities of blue-grean algae were noted in tributaries to the upper Bay during 1970 and 1971 coincident with increases in the concentrations of nutrients in the same area (Clark, Donnelley and Villa, 1973).

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Although a number of studies have reviewed the general effects of increased production of algae in Chesapeake Bay (e.g., Roberts, et al., 1975), the extent of the changes in parameters of water quality that have occurred have not been fully documented. It has thus been difficult to assess the effects of excessive enrichment on the biota and human uses of the Bay. In this report we attempt to document nutrient-related changes that have occurred in Chesapeake Bay that appear to be related to cultural events, particularly enrichment by the major nutrients in sewage, nitrogen and phosphorus.

Inasmuch as the period of some variations in climate, approximately 20 years (Mock and Hibler, 1976; Hibler and Johnson, 1979), is similar to the duration of the events contributing most to excessive enrichment, the effects of climate are also considered in this report. In addition, a review of the extensive documentation of one major storm, tropical storm "Agnes" in 1972, suggested that short-term (1-2 yr) effects of unusual climatic events are similar in many ways to the longer-term effects of excessive enrichment. Thus, major storms and annual variations in climate must also be taken into consideration in interpreting the less cyclic effects of enrichment.

This report is written in several chapters, reflecting not only the division of labor among the contributors and the topicality of reports intended for later publication in the refereed literature, but also the contractual arrangement with E.P.A. agreed to in the scope of the work for this project. The primary purpose of this report is to describe and document historical changes that have occurred in Chesapeake Bay. It will contribute information useful to E.P.A. in compiling the "state of the Bay" report at the end of the Chesapeake Bay Program. Related papers that were also produced as part of the same Chesapeake Research Consortium project and which complement this report are those by Webb (1980) and Neilson (1980). Webb discussed the process of eutrophication, and provided conceptual models of trophic relationships at different levels of enrichment. Neilson discussed effects of enrichment on ecosystem health. This paper is part of the series of products of Grant No. R806189010 from the Chesapeake Bay Program of the U.S. Environmental Protection Agency to the Chesapeake Research Consortium, Inc. That support and the interest and continued assistance of the staff of the Program are acknowledged with appreciation.

EPA-287 (Cin.)
(4-76)

CHAPTER A

CLIMATIC VARIATION

Two major climatic variables have the greatest physical effect on Chesapeake Bay. These are temperature and rainfall, the latter affecting freshwater flows. A special climatic feature, the tropical storm, sometimes produces unusual floods. Such storms have catastrophic effects on the biota of the Bay, some of which are discussed below.

Recent analyses have shown that spatfall of the American oyster, *Crassostrea virginica*, is a major determinant of eventual commercial catch and is closely related to a number of climatic variables (Ulanowicz, Caplins, and Dunnington, 1980). Commercial catches of striped bass also appear to vary in a way correlated with climate (Merriman, 1941; Heinle, Flemer, and Ustach, 1977). As the amount of variation in catch that is accounted for by climatic factors is large (Ulanowicz, Caplins, and Dunnington, 1980), those factors must be considered in the interpretation later in this report of the effects of enrichment on Bay biota, particularly those species whose population size is highly dependent on year-to-year variations in recruitment.

There is growing evidence of cyclic variations in global climate that are closely related to the frequency of solar flares (sun spots) (Mock and Hibler, 1976; Hibler and Johnson, 1979). The period of the solar cycle (approximately 20 yr) appears to be reflected in regional climate (Ulanowicz, Caplins, and Dunnington, 1980). A cycle of about 20 yr seems also to be present in deviations from average winter air temperatures (Fig. A-1). While there are exceptions, clearly a cluster of colder than normal winters between 1961 and 1971 was preceeded by a somewhat longer period when winters were milder than normal (Fig. A-1). Annual mean Bay water temperatures have also fluctuated in a periodic fashion as shown by Schubel (1972) (Fig. A-2) for a slightly different time period than that shown in Figure A-1. The data compiled by Schubel suggest a cycle of approximately 18 to 20 yr imposed on a longer-term general rise in temperatures in Baltimore Harbor. There are also cycles with shorter periods. Figure A-3 shows the mean water temperatures for 1939 through 1977. Extremely cold winters occurred with a frequency of 6 to 8 yr.

Freshwater flow has many effects on the Bay ecosystem (see review by Snedekar et al., 1977), including effects on nutrient inputs and ratios. The input of nutrients to the Bay is to a large extent proportional to freshwater flow, and the ratios of nitrogen to phosphorus also are affected (Guide and Villa, 1972). Ratios of nitrogen to phosphorus in the input also vary significantly from tributary to tributary (Jaworski, 1980). Figures V-18 through V-23 of Guide and Villa (1972) show the excellent linear relationship

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 237)
© U.S. GOVERNMENT PRINTING OFFICE 1980-660-632
TYPING GUIDE SHEET

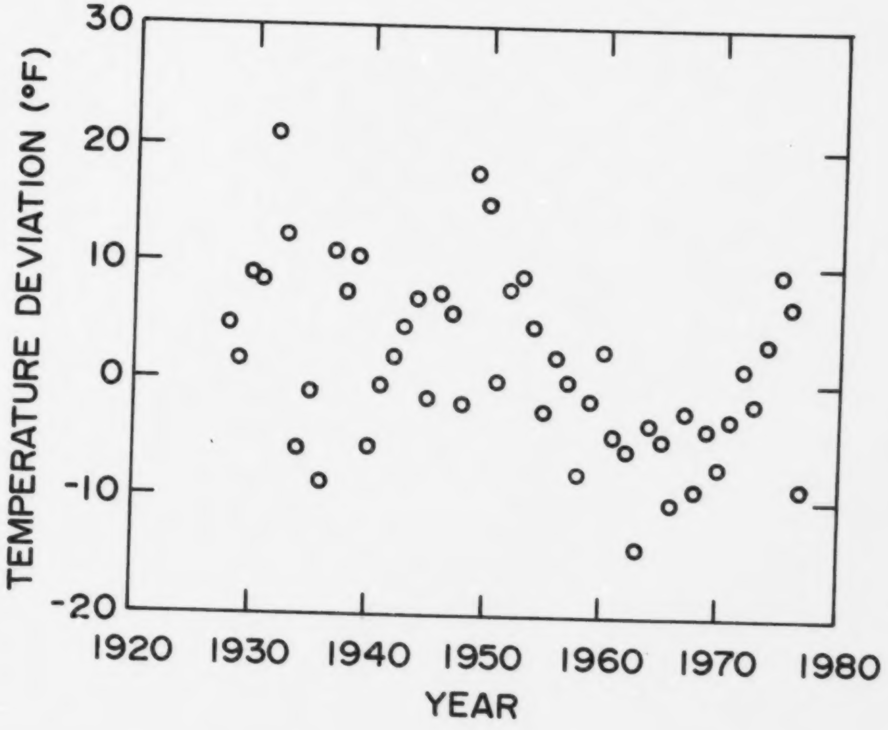


Figure A-1. Deviations from long-term average winter air temperatures at Baltimore-Washington Airport.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 247)
© U.S. GOVERNMENT PRINTING OFFICE: 1980-660-638
TYPING GUIDE SHEET

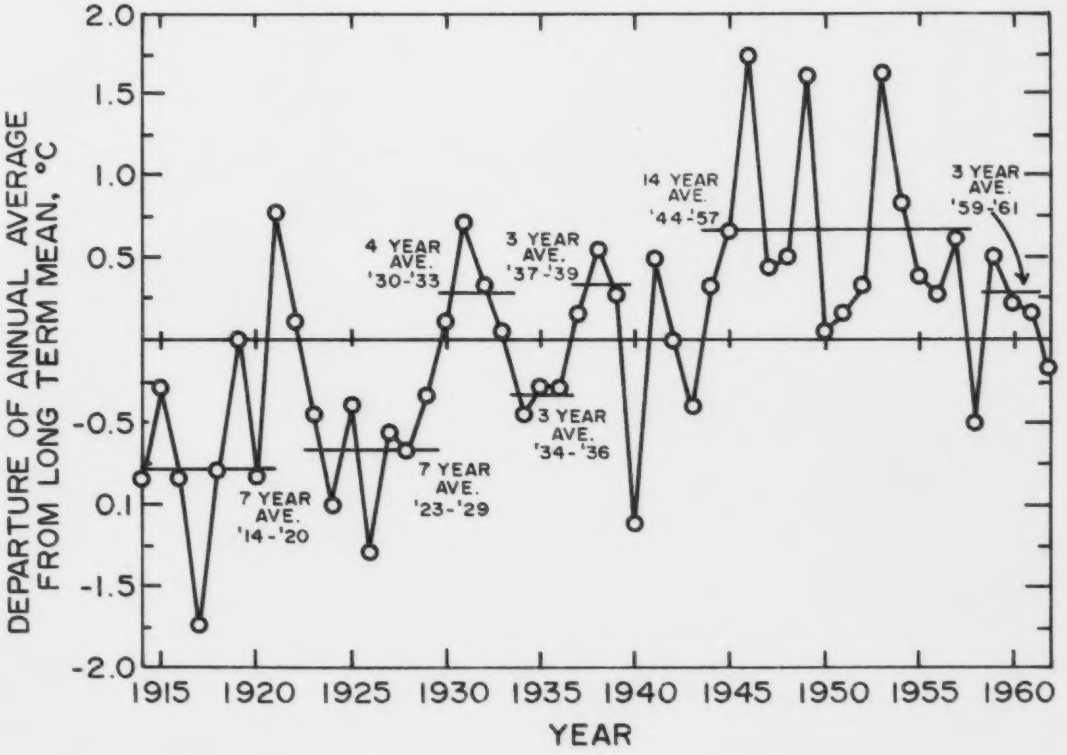


Figure A-2. Departures of mean annual surface water temperatures from 49-year (1914-1962) surface temperatures off Fort McHenry (Baltimore Harbor). Mean surface temperatures averaged over periods of several years are also shown. (Redrawn from Schubel, 1972)

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 247)
TYPING GUIDE SHEET

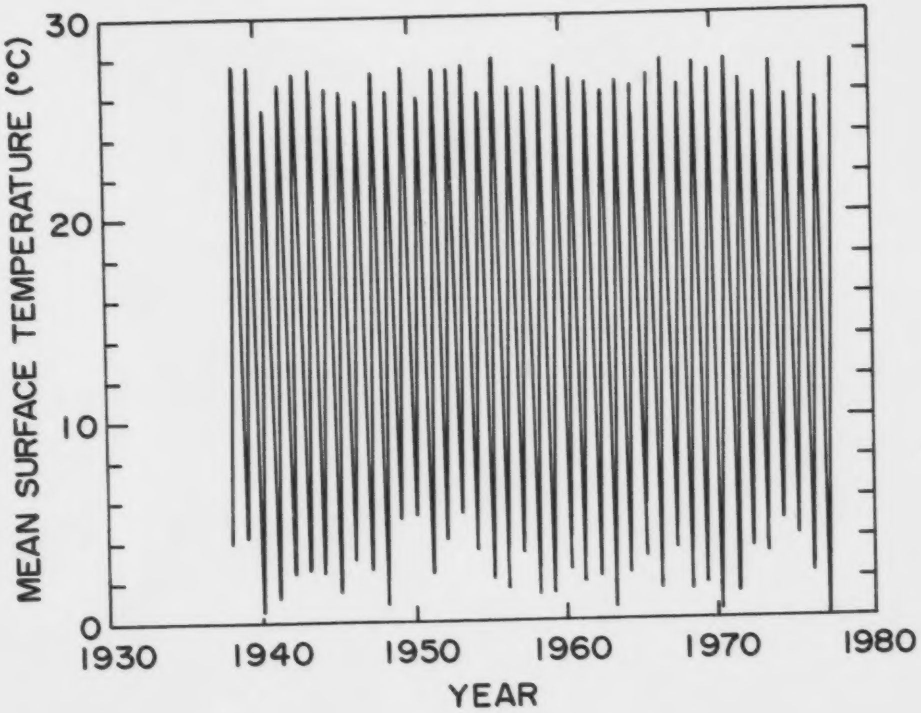


Figure A-3. Monthly mean surface water temperatures at Solomons, Md. from 1937-1976.

between the logarithm of flow and the logarithm of input of nutrients to the head of Chesapeake Bay.

There is no apparent cycle in the variations in freshwater flow to the Bay (Table A-1). The highest annual mean flow shown in Table A-1, for 1972, was above normal because of tropical storm "Agnes."

Average flows during some years are greatly enhanced by exceptional storms such as hurricanes (e.g., 1972 in Table A-1). Truitt (1968) reviewed

Table A-1. Annual mean freshwater flows to all of Chesapeake Bay (cubic feet per second) for 1951-1979.

Year	Bay Annual Average
1951	82,100
1952	94,300
1953	72,800
1954	58,700
1955	73,400
1956	76,000
1957	64,400
1958	81,400
1959	66,400
1960	77,300
1961	78,000
1962	64,800
1963	52,400
1964	61,900
1965	49,000
1966	53,300
1967	77,200
1968	60,100
1969	54,900
1970	77,200
1971	79,000
1972	131,800
1973	95,200
1974	76,900
1975	103,100
1976	84,400
1977	80,100
1978	91,300
1979	113,800

EPA-207 (Cin) (4-76)

the major storms affecting Chesapeake Bay and the coastal areas of Maryland and Virginia through between 1649 and 1967. Those major storms and two additional hurricanes are summarized in Table A-2. Some of the reported hurricanes did not cause heavy rains throughout the region, or Truitt (1968) in some cases did not mention rainfall. Those that are known to have caused flooding are noted in Table A-2.

Table A-2. Major recorded storms and hurricanes between 1649 and 1979 (1649-1967 from Truitt, 1968) affecting Chesapeake Bay and coastal Maryland and Virginia. Storms recorded by Truitt which apparently did not seriously affect Chesapeake Bay were excluded.

Year	Type of Storm	Heavy Rain
1649	Extratropical	?
1667	Hurricane	?
1894	Hurricane	?
1904	Hurricane	?
1911	Hurricane	?
1912	Hurricane	?
1933	Hurricane	?
1936	Hurricane	Yes
1954	Hurricane	Yes
1955	2 Hurricanes	Yes
1972	Hurricane	Yes
1979	Hurricane	Yes

Smaller tributary watersheds are subjected to storms affecting river flows more frequently than in the Chesapeake Bay basin as a whole. Storms affecting the Patuxent River watershed were summarized by the Philadelphia Academy of Natural Sciences, Benedict Estuarine Laboratory, and provided for our use. Their summary is shown in Table A-3 including measured rainfall at Prince Frederick, Maryland, and sometimes at Solomons. Variations in the intensity of storms within the Patuxent basin are shown by the three storms listed for 1969 (Table A-3). Precipitation at a single location does not fully predict the hydrograph for a tributary. For example, there was a very large peak in runoff during September of 1968 in the Patuxent (Flemer, et al., 1970) which was not preceded by abnormally heavy rainfall at Prince Frederick (Table A-3). Since most major tributaries are now gauged, detailed records of freshwater flow exist and can be used to calculate nutrient inputs (e.g., see Guide and Villa, 1972 or Jaworski, 1980).

The salinity of Chesapeake Bay at a fixed point provides a good integration of short-term variations in freshwater flow and thus a smoothed indication of long-term trends. Figure A-4 shows mean surface, extreme high and extreme low salinities at Solomons, Maryland using data from our data base (Appendix A). Note that the variability of salinity is somewhat greater from about 1960 onward than prior to that time. The 1960's were characterized by relatively high salinities while the 1970's have been characterized by relatively low salinities, reflecting the trends in freshwater flows (Table A-1).

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
6-1/2"
9-1/8"
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

Table A-3. Major storms in the Patuxent River Basin (Prince Frederick Data). Courtesy of the Philadelphia Academy of Natural Sciences.

1961	14 July	2.40	inches
1962	10 November	2.00	
1963	29 May	2.94	
	3 June	2.94	
	16 September	2.43	
1966	20 September	2.30	
	19 October	3.86	
1967	February snow totalling 17.5 inches		
1968	13 June	1.43	
	12 November	2.74	greatest one-day precipitation
1969	12 July	1.86	(Prince Frederick)
	23 July	11.85	(Solomon's)
	20 August	2.24	(Prince Frederick)
	20 August	5.13	(Solomon's)
1970	14 April	1.89	
	25 May	1.83	
1971	16 May	2.75	
	4 August	2.95	
	10 October	2.73	
	25 November	2.05	
1972	22 June	3.20	Tropical Storm Agnes
	2 September	1.45	Tropical Storm Carrie
	14 November	1.68	
1973	2 February	1.90	
	9 December	1.98	
1974	30 March	2.20	
	4 September	2.74	
1975	26 June	1.93	
	13 July	2.90	
	23 September	2.05	
1976	16 September	2.87	
1977	14 October	2.31	

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE

CENTER OF PAGE

TOP OF IMAGE AREA

DROPPED HEAD: BEGIN SECTIONS HERE

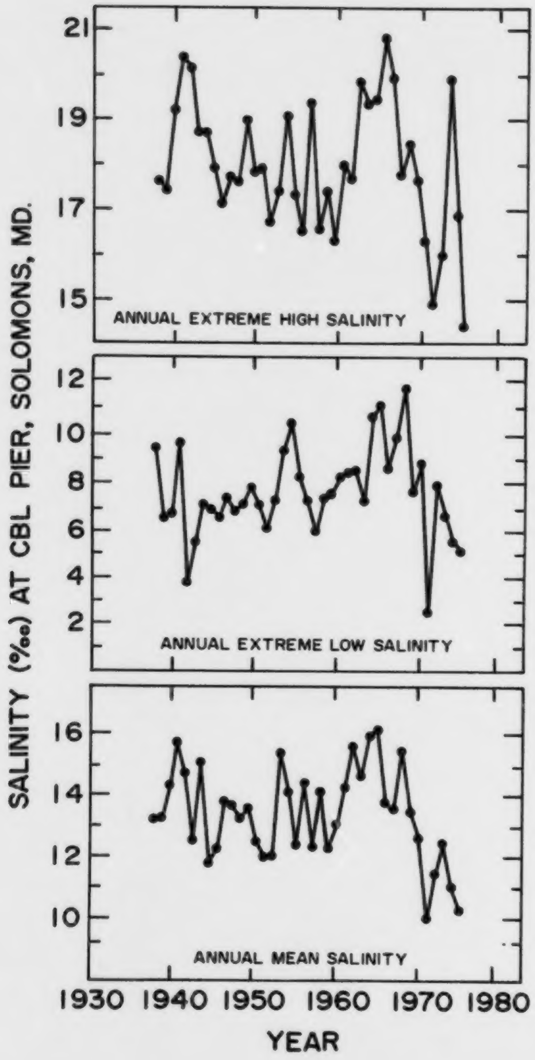


Figure A-4. Annual extreme high salinity at Solomons, Md. (upper panel); annual extreme low salinity (middle panel); and annual mean salinity (lower panel) from 1937 to 1976.

BEGIN LAST LINE OF TEXT

BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

3/8"

PAGE NUMBER

EPA-287 (Cin.)
(4-76)

Some of the effects of major storms on Chesapeake Bay are similar to those of chronic excessive enrichment (discussed in Chapter C). The effects of one tropical storm, "Agnes," in 1972 have been extensively documented (Chesapeake Research Consortium, 1977). That storm, which deposited in excess of 10 inches of rainfall in many parts of the Bay watershed (Astling, 1977), caused apparent increases in heterotrophic activity within parts (and presumably much) of the Bay (Zubkoff and Warinner, 1977; Flemer, Ulanowicz, and Taylor, 1977). The large flows of freshwater reduced concentrations of phytoplankton in the upper Patuxent (Flemer, et al., 1977) but caused increases in phytoplankton concentration down-river by displacement or stimulation of growth (Zubkoff and Warriner, 1977). Concentrations of nitrogen were increased in the lower Bay while concentrations of phosphorus were unaffected (Smith, MacIntyre, Lake and Windsor, 1977). In the upper Bay, the various forms of nitrogen increased, nitrate and nitrite being from 2 to 3 times above normal, whereas, in the lower Bay, concentrations of phosphorus were not affected (Schubel, Taylor, Grant, Cronin and Glendening, 1977). The crops of phytoplankton produced by the influx of nutrients (Flemer, et al., 1977; Zubkoff and Warriner, 1977) appear to have been moderated by the shading effect of the large amounts of sediment brought into the Bay by the storm.

Concentrations of dissolved oxygen were lower after the storm in the bottom waters of some tributaries, presumably a consequence of increased heterotrophic activity and enhanced vertical stratification of the water column as a result of high flows (Flemer, et al., 1977; Hyer and Ruzecki, 1977). In the main stem of Chesapeake Bay, where concentrations of oxygen are naturally low during the summer months (Newcombe and Horne, 1938), the concentrations of dissolved oxygen following "Agnes" were not demonstrably lower (Schubel and Cronin, 1977). Flemer et al. (1977) noted that a storm in August of 1969 (Table A-3) carried an amount of sediment to the Patuxent similar to that brought in by "Agnes." Tributaries to the Bay may well suffer the effects of extreme climatic events much more frequently and severely than the main stem of the Bay (c.f. Tables A-2 and A-3).

The full set of climatic data used in our analyses is available through the University of Maryland computer system. A listing of the variables used is shown in Table A-4. Documentation of programs for retrieval of the climatic data are in Appendix A of this report.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE 1980-660-630
TYPING GUIDE SHEET

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Table A-4. Climatic data.

A	Annual Average Salinity
B	Annual Average Water Temperature
C	Annual Average Air Temperature
D	Annual Average Precipitation
E	Annual Cumulative Excesses Salinity
F	Annual Cumulative Excesses Water Temperature
G	Annual Cumulative Excesses Air Temperature
H	Annual Cumulative Excesses Precipitation
I	Annual Cumulative Deficits Salinity
J	Annual Cumulative Deficits Water Temperature
K	Annual Cumulative Deficits Air Temperature
L	Annual Extreme Values Salinity +
M	Annual Extreme Values Salinity -
N	Annual Extreme Values Water Temperature +
O	Annual Extreme Values Water Temperature -
P	Annual Extreme Values Air Temperature +
Q	Annual Extreme Values Air Temperature -
R	Annual Extreme Values Precipitation +
S	Annual Episodes Salinity +
T	Annual Episodes Salinity -
U	Annual Episodes Water Temperature +
V	Annual Episodes Water Temperature -
W	Annual Episodes Air Temperature +
X	Annual Episodes Air Temperature -
Y	Annual Episodes Precipitation +
Z	Annual Episodes Precipitation -

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

CHAPTER B

NUTRIENT INPUTS

CURRENT INPUTS

There are three categories of sources of major nutrients (nitrogen and phosphorus) to Chesapeake Bay. These are (1) natural non-point sources from native ecosystems--forests and marshes, (2) non-point sources from perturbed ecosystems such as agricultural land and developed areas, and (3) point sources, predominantly sewage treatment plants, but also including industrial sources. Detailed compilations of all of these sources have never been made, and were beyond the scope of this project. Jaworski (1980) did, however, estimate total nutrient loadings to Chesapeake Bay for the period 1969 to 1971 from a variety of sources including direct measurements of flows and concentrations and previously established statistical relationships (e.g., see Guide and Villa, 1972). Loadings for earlier and later periods were estimated for the Patuxent, Potomac and all of Chesapeake Bay including tributaries. A summary of Jaworski's (1980) calculations is shown in Table B-1, which reproduces his Table XII. Jaworski considered direct municipal and industrial discharges, atmospheric sources, and contributions from the upper basins of the Susquehanna River and other tributaries of the Bay. Point discharges above the fall line of the Susquehanna and tributaries to the Bay were not distinguished from non-point sources. The relative contributions from direct discharges to tidewater and from upland sources are shown in Table B-2 [after Jaworski's (1980) Table V].

Brush (1974) summarized all of the sewage discharges in the Chesapeake Bay basin during 1973. His summary was based on actual flows in most cases or design flows, in unspecified instances from operating records or NPDES permits, and included industrial discharges "where known," presumably from NPDES permits. Municipal discharges above the fall line of the Susquehanna and other major tributaries were totalled and listed as a single point source at the fall line. Treated sewage constituted about 2.7 percent of the total freshwater flow to Chesapeake Bay, based on the data of Brush (1974) and the 27-year average flows calculated from streamflow data of the U.S. Geological Survey (Table B-3). The percentage in three tributaries in which some problems have been caused by enrichment was higher, up to 4.8 percent in the Potomac (Table B-3).

The summary by Brush (1974) of the upland point sources allows the calculation of maximum nutrient inputs from sewage and industry for comparison with the total inputs calculated by Jaworski (1980). If we assume that secondary treatment is applied at all discharges, concentrations from the literature, specifically those calculated from the data of Jaworski, et

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER

EPA-287 (Cin.)
(4-76)

Table B-1. External nutrient loading for Chesapeake Bay and its estuaries (1969-1971) (from Jaworski, 1980).

Water Body	Ecological Description	Surface Area (m^2) (10^6)	Volume (m^3) (10^6)	Average Depth (m)	Average Retention Time (yr)
1. Patuxent	Eutrophic	137	660	4.8	1.70
2. York	Non-eutrophic	210	910	4.3	0.72
3. Rappahannock	Non-eutrophic	400	1,780	4.5	1.27
4. James	Eutrophic	600	2,400	3.6	0.39
5. Potomac	Hyper-eutrophic	1,250	7,150	5.8	1.07
6. Chesapeake Bay	Localized eutrophic conditions				
(Including Tribs)		11,500	74,000	6.5	1.16
(Excluding Tribs)		6,500	52,000	8.4	1.32

	External Phosphorus Loading (g/yr) (10^6)	External Phosphorus Loading ($g/m^2/yr$)	External Phosphorus Loading ($g/m^3/yr$)	External Nitrogen Loading (g/yr) (10^6)	External Nitrogen Loading ($g/m^2/yr$)	External Nitrogen Loading ($g/m^3/yr$)	Atomic N/P Ratio of Loading
1.	250	1.82	0.38	750	5.8	1.4	7
2.	160	0.76	0.18	1,190	5.6	1.3	17
3.	180	0.45	0.10	1,500	3.8	0.8	19
4.	1,780	2.70	0.70	10,300	15.6	4.2	13
5.	5,380	4.30	0.80	25,200	20.2	3.5	11
6.	15,100	1.30	0.20	109,100	9.5	1.5	16
	7,350	1.10	0.10	70,160	10.8	1.3	22

EPA-287 (Cin.)
(4-76)

Table B-2. Annual nutrient budget - Chesapeake Bay (1971) (from Jaworski, 1980).

Source	Phosphorus (kg/day)	Nitrogen (kg/day)
Entire Chesapeake Bay Including Estuaries		
Municipal/Industrial	28,700	87,700
Upper Basin Land Runoff	10,200	195,400
Air	2,500	14,800
Total	41,400	297,900
Chesapeake Bay Proper Excluding Estuaries		
Municipal/Industrial	16,900	45,900
Upper Basin Land Runoff	5,200	131,500
Air	1,400	8,200
Total	23,500	185,600

Table B-3. Twenty-seven year average freshwater flow from data of the U.S. Geological Survey annual summaries of stream flow entering Chesapeake Bay (December, 1951-1978); point sources of sewage (from Brush, 1974) and calculated percent of annual flow that is sewage.

River	27-yr average flow (cfs)	Point Sources of sewage (cfs)	Percent of freshwater that is sewage
Susquehanna	38,800	557	1.4
Patuxent	1,085[1]	41.15	3.8
Potomac	13,900	670	4.8
James	10,100	302	3.0
Chesapeake Bay	75,200	2,034	2.7

[1] Patuxent flows were taken from the Johns Hopkins University (1966) rather than the U.S. Geological Service data.

al. (1971) for the Washington, D.C. area, can be used to estimate total loadings. From Table IV-I of Jaworski, et al. (1971) we find that a discharge of 325.6 mgd in the Washington area resulted in loadings of 24,022 lb day^{-1} of total phosphorus and 59,456 lb day^{-1} of total nitrogen (TKN + NO_3 + NO_2). We calculate 73.8 lb day^{-1} of phosphorus and 182.6 lb day^{-1} of nitrogen per 1 mgd of secondary treated sewage. Using the flows tabulated by Brush (1974) (totals to the mouths of tributaries) and the conversion factors above calculated from the data of Jaworski, et al. (1971) we calculated the amounts of nitrogen and phosphorus entering the Bay from point sources (Table B-4). Table B-4 shows those quantities in kg day^{-1} and in 10^6 g yr^{-1}

Table B-4. Contributions of nitrogen and phosphorus from point source loadings in the Chesapeake Bay basin calculated from the flows determined by Brush (1974) using the conversion factors described in the text.

	Nitrogen		Phosphorus	
River	Kg day^{-1}	10^6g yr^{-1}	Kg day^{-1}	10^6g yr^{-1}
Susquehanna	28,841	10,527	12,061	4,402
Patuxent	2,203	804	890	325
Potomac	38,864	14,185	14,495	5,290
Rappahannock	795	290	321	117
York	323	118	131	48
James	16,151	5,895	6,528	2,383
Chesapeake Bay (including tributaries)	108,916	39,754	44,020	16,067

for comparison with the totals of Jaworski (1980) (Table B-1). There are some discrepancies between our calculations (Table B-4) and those of Jaworski (Table B-1). Our estimates of loadings of both nitrogen and phosphorus were higher than Jaworski's (1980) estimates for both the Patuxent and James Rivers. It is possible that losses through deposition of phosphorus and denitrification of nitrogen from point sources in the upper watershed exceed the total non-point contribution, but that seems unlikely. For the Potomac, Rappahannock and York Rivers, we calculated lower loadings from point sources (Table B-4) than Jaworski found for total loadings (Table B-1). The estimated amounts of phosphorus were nearly identical in both cases, but there is evidence for loss of phosphorus in the riverine portions of tributaries (Kemp and Boynton, pers. comm.; Table B-5). For Chesapeake Bay including tributaries we calculated that slightly less nitrogen and slightly more phosphorus came from point sources (Table B-4) than Jaworski estimated for total loadings (Table B-1). Our estimates of point source contributions

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD, BEGIN SECTIONS HERE
9-1/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Table B-5. Comparison of total upland loadings of nitrogen and phosphorus reported by Guide and Villa (1972) and Jaworski (1980) with potential upland loadings from point sources calculated from the flows reported by Brush (1974). Percentage contributions from non-point sources were calculated using assumption of total conservation of nitrogen.

	Nitrogen			Phosphorus	
River and Author	A. Reported in lit.	B. Calculated Potential	Calculated % non-point	A. Reported in lit.	B. Calculated Potential
Susquehanna					
Jaworski (1980)	131,500	28,841	78	5,200	12,061
Guide & Villa (1972)	111,584		74	4,884	
Patuxent					
Guide & Villa (1972)	2,722	1,658	39	740	670
Potomac					
Jaworski (1980)	26,880	6,051	77	2,080	2,445
Guide & Villa (1972)	41,730		85	3,404	
Rappahannock					
Guide & Villa (1972)	3,402	663	81	237	268
York					
Guide & Villa (1972)	2,994	212	93	296	84
James					
Guide & Villa (1972)	15,195	7,460	51	1,084	3,015

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD, BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
9-1/8"
6-1/2"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

(Table B-4) were very similar to those of Correll (1976), arrived at by only slightly different methods, both being approximately 100-120 tons day^{-1} of nitrogen and 48-53 tons day^{-1} of phosphorus. Thus, Jaworski's (1980) estimates of total loading to Chesapeake Bay may be low, as Correll (1976) calculated that nearly equal amounts were contributed by non-point sources, with considerable seasonal variation. The apparent large differences in estimates of loadings to Chesapeake Bay made by various authors strongly illustrate that loading rates must be measured, not estimated, if they are to be known with useful accuracy.

Jaworski (1980) estimated total upland loadings for the Potomac River and for the Chesapeake Bay excluding tributaries (presumably from data for the Susquehanna River) based on actual flows and concentrations for selected periods (Jaworski, pers. comm.). Guide and Villa (1972) did the same for several tributaries. As Brush (1974) totalled the volumes of known point sources in all river basins above the fall lines, we were able to make an additional comparison. Table B-5 shows a comparison between the total loadings calculated by Guide and Villa (1972) (converted from PO_4^{-3} to PO_4^{-3} as P) and Jaworski (1980) and the point source totals calculated from the flows reported by Brush (1974) as we did for Table B-4. The potential amounts of nitrogen from point sources in the upland part of the basins were considerably less than the total contributions reported by Jaworski (1980) and by Guide and Villa (1972) (Table B-5). The potential contributions of phosphorus from point sources were considerably higher than the total loadings reported by Jaworski (1980) for the Susquehanna and James. The possibility of temporary sedimentation in the reservoirs or stream beds has been suggested by Guide and Villa (1972) and by Clark, Guide and Pheiffer (1974). The potential contributions of phosphorus from point sources in the Potomac basin were slightly higher than the total loadings reported by Jaworski, and slightly lower than those of Guide and Villa (1972) indicating that sedimentation may have also occurred in the Potomac. Although long-term net deposition of sediment in the upper Potomac River is unlikely, sediment may be deposited over short periods with scouring occurring during severe storms. Jaworski has indicated that he generally could not account for all of the phosphorus entering the upper Potomac River in his sampling at the fall line. Percentages of loading of nitrogen from non-point upland sources from Table B-5 are similar for the two basins; 78 percent for the Susquehanna and 77 percent for the Potomac based on Jaworski (1980) estimates. Based on the loading estimates of Guide and Villa (1972), non-point sources constitute from 39 percent (in the Patuxent River) to 93 percent (in the York River) of the total upland contributions of nitrogen. Because of the apparent temporary loses in the watershed, presumably caused by temporary deposition of sediments in the River bed, a similar calculation was not made for phosphorus. As these calculations of percentages are based on the assumption of conservation of nutrients and the sewage flows reported by Brush (1974), they are minimum estimates.

Correll (1976) presents data in his Table 5 which allow calculation of the annual average percentage contribution of non-point sources of nitrogen and phosphorus to the Bay as a whole of 53.2 and 44.6 percent respectively. As Correll's (1976) estimates include the large point sources at Baltimore, Washington, Richmond and Hampton Roads-Norfolk, the fact that they are in general lower than our estimates for percent nitrogen from non-point upland sources for the major tributaries (except the James) (Table B-5) suggest that we are in the correct range. The apparent discrepancy between our estimated minimum non-point contributions of phosphorus from the Susquehanna and James Rivers (Table B-5) and the Bay-wide estimates of Correll are not encouraging. Correll (1976) also used the sewage flows reported by Brush (1974) and an assumption of conservation of nutrients in his calculations.

If denitrification occurred in the upper basins, a possibility suggested by recent work in the estuarine part of the Potomac (Kaplan, et al., 1978; McElroy, et al., 1978; Elkins, Wofsy and McElroy, 1980), our calculations of percentage nitrogen from non-point sources could be in error. It appears that direct measurement of inputs to the Bay are necessary for the accurate assessment of the relative importance of point and non-point sources.

HISTORICAL TRENDS

Periodic compilations of total discharge or nutrient loadings to Chesapeake Bay do not exist. There are, however, reviews for particular watersheds that indicate trends. Reviews of the type reported by Brush (1974) of total discharge are possible for any time period after implementation of the NPDES permit system. Records available at various state offices should allow the compilation of discharge trends from about 1970 onwards. Such periodic reviews are strongly recommended in the future and would be a useful part of future monitoring efforts.

Many of the changes that occurred in Chespeake Bay, and more particularly in the tributaries, preceded the NPDES system and loading trends must be inferred from more intensively studied watersheds such as the Potomac and Patuxent and from changes in population, land use, and cultural practices. Jaworski, Clark and Feigner (1972) calculated loadings from point sources of nitrogen, phosphorus and carbon to the Potomac River for 1913 to 1970. A recent modification of their Figure 3 is presented here (Figure B-1). The phosphorus loadings used by Jaworski, et al. (1972) are nearly identical to the total loadings given by Jaworski (1980, Table XII) for the same time period (our Table B-1), however, the total estimates of nitrogen input are considerably higher, 69,041 kg day^{-1} in Table B-1 (the 1980 estimate of total loadings) versus approximately 23,000 kg day^{-1} in Figure B-1 (the 1972 estimate of loadings from point sources). The overall trend for nutrient loading is clearly upward with time, except for the recent decrease in phosphorus loading apparent in Figure B-1.

Two additional cultural events are documented in Figure B-1. There is a more rapid increase in phosphorus loadings relative to those of nitrogen from about 1955 onward, which is probably due to the use of phosphorus compounds in detergents. The second apparent feature is the reduction in discharges of carbon between 1960 and 1969 that were accomplished by the implementation of secondary treatment during that period (Anon., 1969a). As documented by Anon. (1969a) and by Jaworski, et al. (1972), advances in treatment capability resulting in reduced carbon (B.O.D.) loadings have, with time, been consistently overcome by continuing growth of the contributing population. As nitrogen concentration is only slightly reduced by secondary

EPA-267 (Cin.)
(4-76)

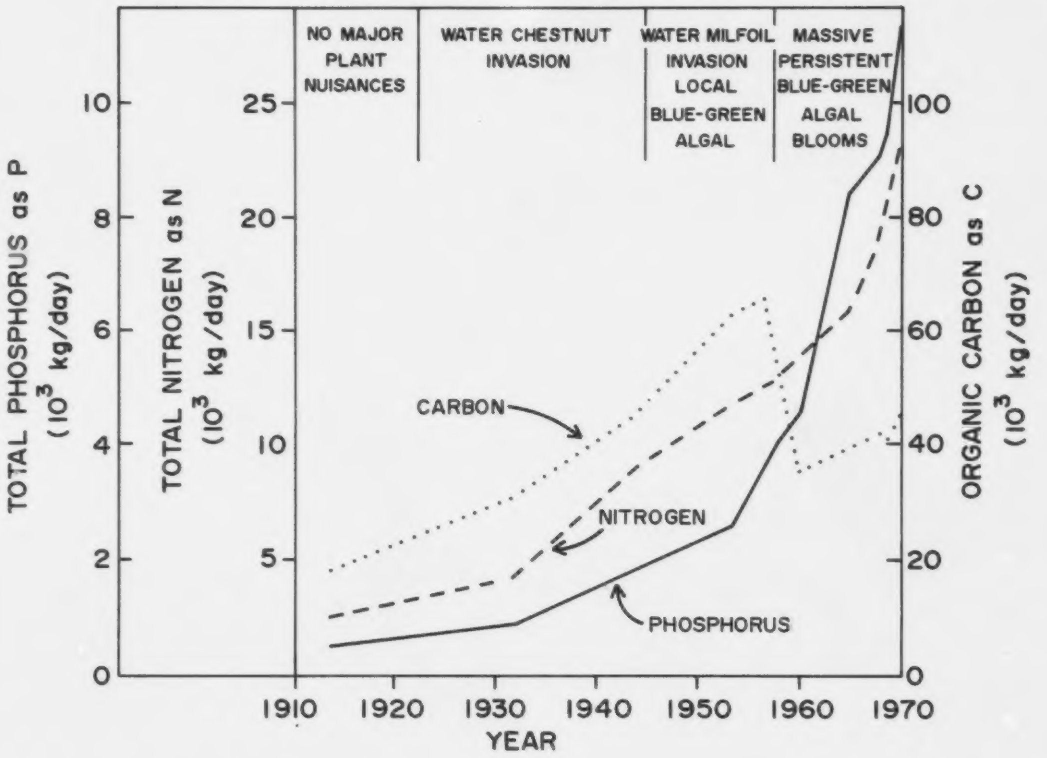


Figure B-1. Nutrient loadings from waste treatment plants in the Washington, D.C., metropolitan area as a function of time (modified from Fig. 3 of Jaworski, Clark and Feigner, 1972).

versus primary treatment, there have been no dramatic reductions in the discharges of that nutrient (Figure B-1).

Population has been increasing throughout the Chesapeake Bay basin, although at different rates in different localities. The lower Susquehanna River basin experienced a population increase of about 10 percent between 1960 and 1970 while the entire State of Pennsylvania increased by 4.2 percent (Anon., 1975). By contrast the population of the Patuxent River basin roughly doubled during the same period, going from 134,000 in 1960 to 260,000 in 1970 (Mihursky and Boynton, 1978). During approximately the same interval, the discharges of sewage to the Patuxent River have increased about ten-fold; from 2.6 mgd in 1963 (Anon., 1974) to 26.6 mgd in 1973 (Brush, 1974), with intermediate flows of about 11 mgd in 1967 (Anon., 1969b). Sewage discharges thus grew at a more rapid rate than population during the 1960's. That largely reflects the advent of sewerage in some areas, and subsequent increases are more likely to be more directly proportional to population growth.

While discharges of nutrients from point sources can be estimated for previous periods from population size and known changes in treatment levels (e.g., Figure B-1), non-point contributions are not so easily calculated. We can be fairly certain that some increase occurs in non-point contributions of nutrients as a result of growth in population because areal yields are in general higher for urban and suburban land than for agricultural and forested areas (Correll, Pierce and Faust, 1975; Correll, 1976). Table B-6 shows the percent of major land uses in the Chesapeake Bay basin and the percentages of total non-point contributions of nitrogen and phosphorus from those areas. Although residential areas comprise only 10 percent of the area, they contribute 40 percent of the nitrogen and 53 percent of the phosphorus from non-point sources. By contrast, the largest land-use category, forest and brushland, which constitutes 52.5 of the total area, contributes only 8.9 percent of the nitrogen and 12.6 percent of the phosphorus from non-point

Table B-6. Percentages of nitrogen and phosphorus contributed from various land-use types [based on annual averages of Correll's (1976) seasonal contributions] (non-point sources only) and the percentage of each land use in the Chesapeake Bay basin (from Correll, 1976). Open water and freshwater wet areas were not included.

		Nitrogen	Phosphorus
Land use	Percent of basin area	Percent of total non-point sources	Percent of total non-point sources
Forest and brushland	52.5	8.9	12.6
Cultivated cropland	24.0	38.0	19.3
Pastureland	13.0	17.4	13.4
Residential areas	10.0	40.4	53.0

sources. Pastureland and cultivated cropland are intermediate; contributing phosphorus in approximate proportion to their area and contributing nitrogen at a higher proportion than their area. Urbanization at the expense of forest, pasture or cropland would lead to increases in non-point contributions of both nitrogen and phosphorus.

Urban and "other" land uses appear to be increasing in the Susquehanna River basin at the expense of cropland and pastureland (Table B-7). The greatest increase predicted by the U.S. Department of Agriculture (Anon., 1969c) was in the "other" category: an unfortunate grouping of highways undeveloped urban fringes (brushland and woodland?), recreational areas (parks?), and "public institutions" (prisons to military reservations?). During the same period, urban land was projected to increase only from 4.2 to 5.5 percent of the total land area (Table B-7).

Table B-7. Land use in the Susquehanna River basin in 1964 and projected for 1985 by the U.S. Department of Agriculture (Anon., 1969c).

	Percent of total land	
Land Use	1964	1985
Cropland	23.9	12.5
Pastureland	9.5	6.7
Forest land	55.6	57.4
Urban	4.2	5.5
Other	6.8	18.0

Another indication of trends in the Susquehanna basin can be obtained from Figure B-2, adapted in part from the cover of the 1973 Crop and Livestock Annual Summary for Pennsylvania (Anon., 1973), and from Mihursky and Boynton (1978). Figure B-2 shows that in both the State of Pennsylvania, of which the Susquehanna basin occupies about one-half, and the much smaller Patuxent basin, the amounts of agricultural lands are decreasing. In the Patuxent, urban areas are growing rapidly in contrast to the Susquehanna basin (Table B-6).

The decrease in agricultural lands does not necessarily mean that non-point contributions of nutrients from agriculture are decreasing. The diminished agricultural areas are apparently receiving larger amounts of chemical fertilizers than were applied to larger areas in the past, and suburban lawns are often fertilized in excess. Figure B-3 shows the amounts of chemical fertilizer sold at selected times in Pennsylvania and Maryland (adapted from Hargett and Berry, 1978). All data are expressed as tons (English) of each major nutrient. Data for Virginia are similar to those for

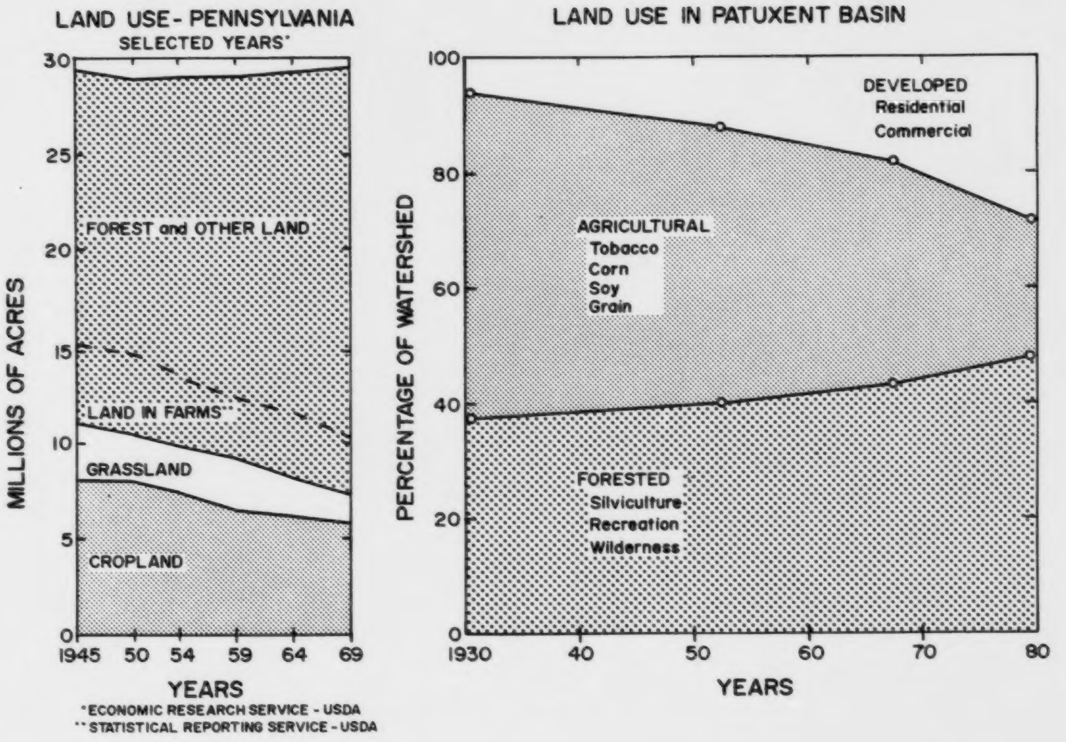


Figure B-2. Land use in the State of Pennsylvania (from Anon., 1973) and in the Patuxent River basin (from data of Mihursky and Boynton, 1978) as functions of time.

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA

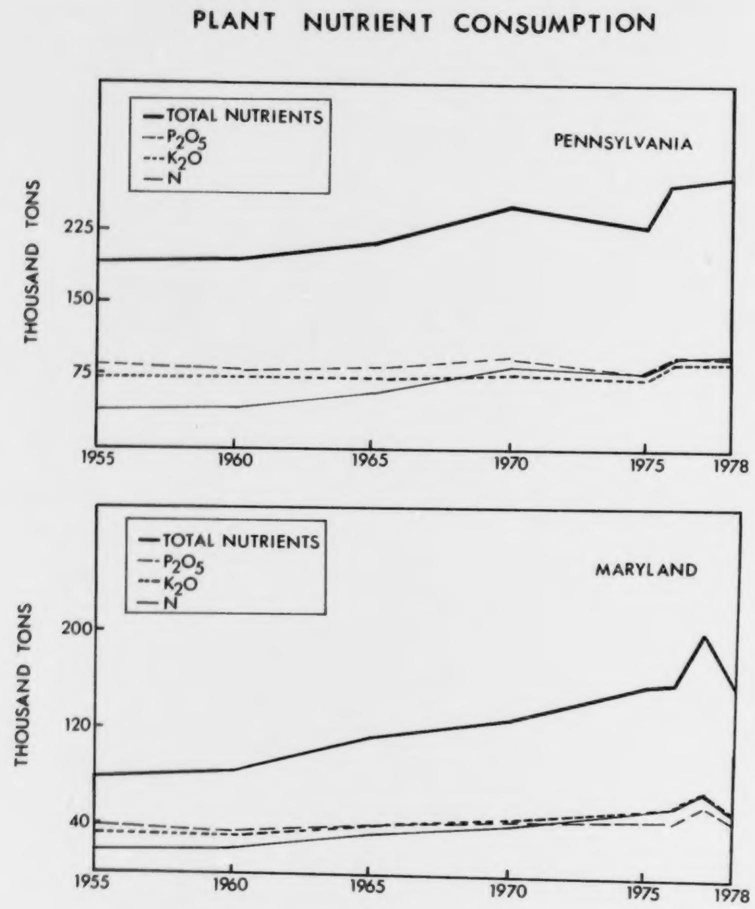


Figure B-3. Sales of fertilizer in Pennsylvania and Maryland during selected years (from Hargett and Berry, 1978). The sales in Virginia (not shown) were nearly identical in scale and pattern to the data from Pennsylvania. All data as tons of major nutrient.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
5/8"

PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 261)
U.S. GOVERNMENT PRINTING OFFICE
TYPING GUIDE SHEET

Pennsylvania, even to scale, and are therefore not shown. The increases in use of some particular forms of fertilizers have been even more dramatic, particularly nitrogen solutions in Maryland (Fig. B-4) and Virginia (patterns similar to Maryland, except for scale) and of nitrogen solutions and urea in Pennsylvania (Fig. B-4). The data in Fig. B-4 are unfortunately expressed as total tons of material sold (i.e., not normalized to total nitrogen as in Fig. B-3).

Increased application of fertilizer (Figs. B-3 and B-4) to diminished land areas (Fig. B-2) does not necessarily mean increased contribution of nutrients in runoff. Phosphorus yields from agricultural lands are closely related to erosion, so the increased use of minimum-tillage procedures should reduce non-point contributions of phosphorus. It has been reported outside the literature that approximately 80 percent of the nitrogen applied to test plots of corn in Maryland over a three-year period was recovered in the crops and soil under either no-till or conventional tillage procedures (Bandel, pers. comm.). With plowing, the nitrogen was distributed deeper in the soil profile, reflecting the physical disturbance. Correll, Wu, Friebele and Miklas (1977) reported 39 percent of added nitrogen as agricultural output from pasture and hay land and 61 percent as agricultural output from cropland. They also indicated either net gains in nitrogen or losses to the atmosphere in their study area. In an experimental sewage disposal system at Cape Cod, Massachusetts, approximately 40 percent of the nitrogen applied as sewage was recovered in forage crops (Deese, Vaccaro, Ketchum, Bowker and Dennett, 1977). Crop yield was directly proportional to application rates of up to 7.5 cm per week, suggesting a high affinity for nitrogen by plants in nitrogen-limited terrestial systems.

There is one encouraging aspect to the relatively high yields of nutrients from non-point sources in residential and urban areas (Table B-5). Collection and treatment of runoff from those areas is considerably more feasible than from natural or agricultural areas. The high recovery rates of nitrogen from agricultural crops and soils is also encouraging, indicating that with appropriate farming practices, nutrient losses can be minimized. These benefits must be balanced against the potential hazards of herbicides to aquatic ecosystems.

PESTICIDES

The reductions in nutrients losses and consumption of energy that are accomplished by minimum tillage agriculture have been accompanied by increases in the application of herbicides, an unknown fraction of which reach Chesapeake Bay. The use of selected herbicides in Maryland and Virginia counties bordering on the Bay and lower reaches of tributaries has been summarized by Stevenson and Confer (1978). Their Tables 75 and 76 are reproduced here as Table B-8. The uses of some compounds such as Paraquat and Alachlor have increased considerably between 1971 and 1975, while there have been modest increases in others, or even decreases in some cases. The potential effects of herbicides on the primary producers and other organisms in the Bay is not known, but effects have been implied on aquatic vegetation. It is conceivable that herbicides could suppress the usual increases in phytoplankton that accompany enrichment with nutrients.

EPA-287 (Cin.)
(4-76)

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

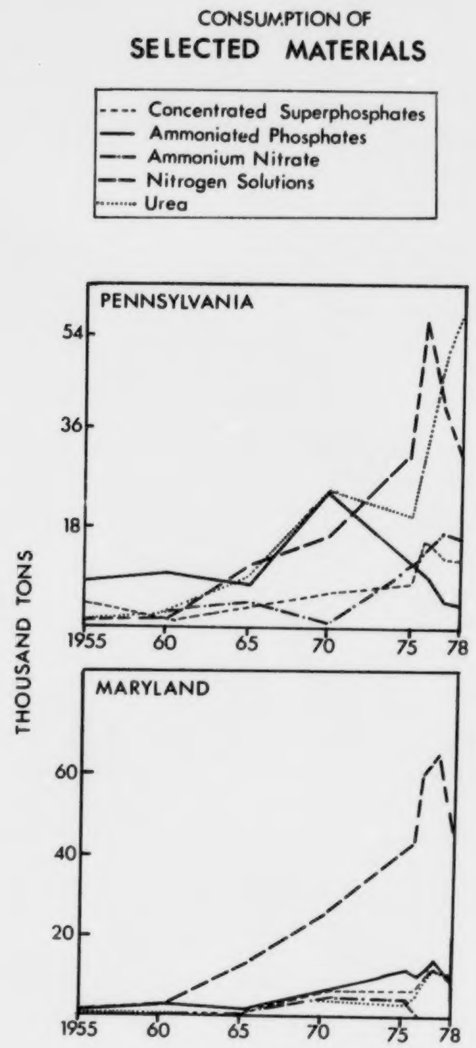


Figure B-4. Sales of selected materials in Pennsylvania and Maryland for selected periods (from Hargett and Berry, 1978). Data from Virginia were similar in pattern to the trends in Maryland, but amounts used (vertical scale on the Virginia figures) were similar to Pennsylvania.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE 1980-660-635
TYPING GUIDE SHEET

Table B-8. Estimated use of several herbicides in Maryland and Virginia counties bordering on Chesapeake Bay and its tidal tributaries (from Stevenson and Confer, 1978).

	Cecil		Kent		Talbot		Carolina		Dorchester	
	1971	1975	1971	1975	1971	1975	1971	1975	1971	1975
Paraquat	454	726	170	2,268	*	4,082	1,134	3,093	1,134	1,701
Atrazine	15,422	*	31,752	45,360	40,370	44,226	13,347	12,474	31,752	24,948
Simazine	1,383	2,268	6,350	11,340	6,917	8,618	2,268	3,904	2,268	6,804
2, 4-D	907	771	765	454	6,124	2,381	1,650	1,633	4,536	1,814
Dicamba	136	181	57	454	2,041	454	550	273	454	454
Dinoseb	3,175	680	14,742	1,089	*	*	8,301	3,121	5,102	3,402
Trifluralin	2,722	680	680	2,722	907	680	1,701	1,252	2,041	3,402
Linuron	1,497	3,402	1,588	4,899	5,443	14,969	5,103	7,770	4,990	4,536
Alachlor	7,825	2,722	8,845	40,824	8,845	36,231	10,206	7,904	3,402	23,814
Total	33,521	11,430	64,949	109,410	70,647	111,641	44,260	42,234	55,679	70,879

	Wicomico		Baltimore		Anne Arundel		Charles		Calvert	
	1971	1975	1971	1975	1971	1975	1971	1975	1971	1975
Paraquat	227	603	517	1,814	*	181	*	170	*	181
Atrazine	12,248	5,443	8,845	9,072	*	8,618	6,350	5,558	4,218	10,773
Simazine	4,649	5,350	5,103	6,804	*	*	454	2,268	295	599
2, 4-D	1,447	2,004	1,021	1,814	*	363	170	510	227	298
Dicamba	842	1,489	284	454	*	*	*	*	*	43
Dinoseb	15,309	17,554	5,783	850	*	*	*	272	137	181
Trifluralin	1,429	1,361	113	953	*	227	*	204	68	91
Linuron	3,175	5,860	204	408	*	204	340	816	771	2,699
Alachlor	10,206	25,855	1,225	2,041	*	567	*	2,722	771	2,699
Total	49,532	66,519	23,095	24,210	*	10,106	7,314	13,630	6,487	17,564

*Data not available.

Table B-8. Continued.

	St. Mary's		Totals		Accomack		Northampton		Pr. William	
	1971	1975	1971	1975	1971	1975	1971	1975	1971	1975
Paraquat	*	680	3,636	16,309	*	449	*	510	91	*
Atrazine	*	9,072	164,304	176,654	*	4,168	*	1,143	581	*
Simazine	*	5,443	29,687	54,398	*	680	*	136	*	*
2, 4-D	*	45	16,847	12,087	*	2,427	*	1,542	3,459	*
Dicamba	*	11	4,364	3,813	*	227	*	397	68	*
Dinoseb	*	91	52,549	27,240	*	*	*	510	*	*
Trifluralin	*	907	9,661	12,479	*	1,157	*	885	*	*
Linuron	*	8,165	23,111	53,728	*	1,012	*	1,111	*	*
Alachlor	*	5,443	51,328	150,822	*	3,289	*	408	159	*
Total	*	29,857	355,484	507,530	*	13,409	*	6,642	4,358	*

	King George		Westmorland		N. Cumberland		Lancaster		Richmond	
	1971	1975	1971	1975	1971	1975	1971	1975	1971	1975
Paraquat	11	391	91	1,030	340	795	11	*	236	*
Atrazine	2,023	3,792	4,419	8,446	4,536	7,376	3,489	*	2,522	*
Simazine	*	1,847	299	900	41	2,803	*	*	27	*
2, 4-D	1,854	386	272	425	1,012	251	370	*	1,474	*
Dicamba	204	45	23	63	*	*	*	*	*	*
Dinoseb	816	68	2,381	1,134	181	81	1,270	*	*	*
Trifluralin	41	136	84	1,433	163	3,147	136	*	231	*
Linuron	113	599	649	2,368	975	1,565	48	*	771	*
Alachlor	*	1,792	363	4,253	1,814	2,211	91	*	91	*
Total	5,062	9,056	8,581	20,052	9,062	18,129	5,415	*	5,352	*

*Data not available.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD: BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

Table B-8. Continued.

	Middlesex		Gloucester		King & Queen		New Kent		York	
	1971	1975	1971	1975	1971	1975	1971	1975	1971	1975
Paraquat	6	850	68	284	*	340	*	499	6	*
Atrazine	2,085	5,117	6,174	7,802	3,647	4,763	*	3,409	102	*
Simazine	*	2,068	68	2,268	*	218	*	1,524	*	*
2, 4-D	261	567	45	45	454	317	*	159	145	68
Dicamba	13	51	5	5	23	7	*	86	23	*
Dinoseb	1,814	204	181	181	*	680	*	544	*	*
Trifluralin	*	361	204	2,858	*	293	*	136	*	*
Linuron	844	1,894	132	2,268	*	680	*	635	23	39
Alachlor	*	794	1,633	10,206	454	3,062	*	2,199	*	*
Total	5,023	11,906	8,510	25,917	4,578	10,360	*	9,191	299	107

	Isle of Wight		Suffolk		Chesapeake		Totals	
	1971	1975	1971	1975	1971	1975	1971	1975
Paraquat	*	102	284	*	*	367	1,144	5,617
Atrazine	10,705	10,977	5,833	*	*	3,958	46,116	60,851
Simazine	54	109	45	*	*	*	534	12,553
2, 4-D	1,089	2,336	1,270	*	*	2,495	11,705	11,018
Dicamba	*	*	*	*	*	*	359	881
Dinoseb	*	12,882	4,082	*	*	1,021	10,725	17,305
Trifluralin	27	113	54	*	*	*	940	10,519
Linuron	34	*	567	*	*	1,792	4,156	13,963
Alachlor	728	24,585	3,719	*	*	9,952	9,052	62,751
Total	12,637	51,104	15,854	*	*	19,585	84,731	195,458

*Data not available.

EPA-287 (Cin.)
(4-76)

CHAPTER C

HISTORICAL CHANGES IN WATER QUALTIY

INTRODUCTION

As documented by McErlean and Reed (1979), the amounts of data that are available to document changes in Chesapeake Bay diminish rapidly as one goes back in time from the present to 1968. By 1968, adverse effects of enrichment had already been noted in some heavily loaded tributaries such as the Potomac (Anon., 1969a), and shortly thereafter concern was being expressed that problems were imminent in other areas such as the Patuxent (Cory and Nauman, 1970; Cory, 1974; Flemer, Hamilton, Keefe and Mihursky, 1970). Thus, by the time an extensive data base for Chesapeake Bay began to develop, about 1968 to 1970 (McErlean and Reed, 1979), many changes had already occurred. Thus we decided that the acquisition of water-quality data pre-dating 1970 was our first priority. Our second priority then became the acquisition of more recent data from areas with a good historical base (i.e., data taken prior to 1968).

In selecting data for development of historical trends we found, at times, that more than one set of data was available for a given area and period of time. This was particularly true after 1970 when the number of studies on Chesapeake Bay increased (McErlean and Reed, 1979). In those cases we generally chose to use the data from studies with the greatest seasonal coverage or that included measurements of parameters of greatest interest.

In addition we planned to obtain as many as possible of the existing data banks on Chesapeake Bay. Automated data systems containing Bay data are maintained by the U.S. Environmental Protection Agency (STORET), the State of Maryland, the U.S. Geological Survey (water quality data mainly from the Potomac estuary), the Smithsonian Institution, The Johns Hopkins University, Chesapeake Bay Institute (C.B.I.), the Virginia Institute of Marine Sciences (V.I.M.S), Baltimore Gas and Electric Company and the Philadelphia Academy of Natural Sciences (P.A.N.S.). Of these eight data systems, only C.B.I. and P.A.N.S. data banks contain data that pre-date system creation. The C.B.I. and V.I.M.S. data bases were given highest priority of the automated systems because of their historical length; 1949 onwards for the C.B.I. system, and about 1954 onwards for V.I.M.S. The E.P.A. STORET system was given high priority early in our project and one tape of data from the Potomac River was acquired. We later deferred work on that tape when it became apparent that there would be considerable difficulties in obtaining and translating all of the available data bases within the time of our contract. Since our sponsor of our project had already access to STORET we deferred working on that system. At the time of this writing, none of the other automated data

EPA-287 (Cin.)
(4-78)

systems have been translated to our format. Instead, arrangements have been made with E.P.A. staff to perform part of the necessary format changes on the Bay Program computer.

During many of the earlier studies on Chesapeake Bay, temperature and salinity were the only parameters of water quality that were measured. We felt that to be a useful indicator of water quality, at least one other parameter from a selected list ("PCODE," pp. 4-5, App. B) should be present. The parameters to be used as indicators of water quality (trophic state) were chosen by consensus among the principal investigators on this project and those choices were later reinforced by discussions at the Workshop in March of 1979 and at the Symposium in May of 1979 (Neilson and Cronin, 1980). Of the data sets we reviewed (Appendix B) we selected for inclusion only data that contained at least one parameter from our "PCODE" list, usually, but not always, in addition to temperature and salinity. The same criterion was applied to our translations of the C.B.I. and V.I.M.S. data bases. Those data bases could be made available in their entireties, in their original formats.

In some cases, data were made available to us for our review from continuing studies. In most of those instances, mainly involving recently (post-1970) taken data, the data were not included in our data base (Appendix B) but will be cited by source where used. Most of those data are eventually destined to be in one of the automated data systems mentioned above. In some instances original data of great historical value could not be obtained. In those cases, for example the early work of Patten, Mulford and Warriner (1963) on the lower Bay, we extracted approximate values from published figures. These are appropriately qualified in the text, and the sources cited. Where original data included in our data base (Appendix B) were more complete (i.e., tables rather than figures) or equivalent to published values, we have cited both the original source and our acquisition number (in Appendix B).

Several areas of the Bay for which the best (most complete or longest in time) historical data are available are described separately in the following sections. Some areas are reviewed in greater detail in the following sections, particularly the Patuxent River. This generally reflects the availability of data taken over a long time, i.e., the best possibilities of detecting trends. Because many of the methods used to measure water quality were developed or evolved considerably during the period reviewed, we have provided a brief section on comparability of methods, reliability of data and limits of detection. The current trophic state of Chesapeake Bay is addressed in the last section.

METHODS, COMPARABILITY, AND LIMITS OF DETECTION

Quality assurance and the historical data record. In developing the proposal that led to this project, the principal investigators wrestled with the problem of verification of the accuracy of data to be acquired for historical analysis. We finally concluded that no fully satisfactory answer existed. To have attempted to verify every single data entry into our historical data base would have required a gargantuan effort of unfundable proportions. Original data records would have to be acquired, each data value cross-checked, and a decision made about the competence of the analyst and about the appropriateness of the procedures used for sample collection, storage, and analysis. Such an endeavor appeared to be extraordinarily difficult, and perhaps futile. Clearly, quality assurance is not a practical matter after the fact. We thus chose to employ the following guidelines:

1. We would accept all data into our data system except for those values which were clearly erroneous or very suspect.

2. We would provide the best possible documentation of the analytical techniques employed to produce the data.

3. We would identify to the best of our ability data sources and scientists who supervised analyses.

4. We would provide general guidelines in this report about the validity of techniques used in analytical determination.

5. We would include a caveat that discretion must be used in interpreting trends, particularly for analytical values which were obtained using the least reliable techniques.

As we stated earlier in the report, our first priority was to acquire the oldest data possible as it was quite obvious that data frequency has increased markedly with time and it would make little sense to expend all our resources acquiring recent data only. Although we realize that analytical pitfalls may be deepest with those old data, we have been impressed with the care with which analytical determinations were made and with the wisdom of interpretation reflected in some of the early reports (e.g., Newcombe, 1940; Newcombe and Brust, 1940; Nash, 1947).

We are cautious about concluding definitely that water quality has changed from historical trends based on the old data alone; however, we feel the trends evidenced justify present concerns about water quality and should not be discounted arbitrarily.

In the following section of this report we will not exhaustively review the history of quantitative analysis for nutrients or other water quality parameters: a number of excellent reviews have been written (e.g., Wattenberg, 1937; Barnes, 1959; Riley, 1975), but we will attempt to provide some overview and evaluation about the reliability and comparability of older techniques to present ones.

Analytical Methods. The most reliable parameters in the historical data base are transparency measured by Secchi disc, nitrite and dissolved oxygen.

The Secchi disc gives good reproducibility from operator to operator. It adequately permits estimation of the depth of the one percent of ambient light level as three times the Secchi depth.

The earliest method for nitrite determination was based on diazotization of sulfanilic acid by the nitrite followed by coupling to o-naphthylamine to give a rose colored dye (Ilosvay, 1889). The modern technique described by Bendschneider and Robinson (1952) is an a adaptation of Shinn's (1941) method in which sulfanilamide is the diazotizing agent and N-(1-naphthyl) ethylenediamine dihydrochloride is the coupling agent. The sensitivity and simplicity of this method have made it the method of choice for saline waters for nearly 30 years.

Modern oxygen methodology is based on the Winkler (1888) titrimetric method. The essence of the Winkler procedure is a set of chemical reactions which convert dissolved oxygen in the sample to an equivalent quantity of iodine, followed by measurement of the iodine produced. The chemistry is complex but the method is straightforward in application (Garritt and Carpenter, 1966; Carpenter, 1965). The various modifications of the method yield varying results, but these are probably not too significant in the estuary. Thus, the oxygen data for Chesapeake Bay is probably accurate to ±0.5 ml/l for any of the Winkler modifications.

Methods for phosphate and nitrate are generally reliable if the analyst has taken care.

Modern phosphate techniques are based on the molybdate method of Deniges (1920). Wattenberg (1937) discusses an acceptable early procedure and Harvey (1948) applied a method with photoelectric detection. These procedures suffered from color fading, salt errors, long development times and color instabilities. Murphy and Riley (1958; 1962) first suggested ascorbic acid as reductant which gave 60 h color stability and later added antimony which reduced color development to 10 minutes. Jones and Spencer (1963) evaluated five methods. All methods are subject to interference by arsenate and organic phosphates hydrolysed during analysis by sulfuric acid in the reagent. Arsenate interference is minimized with the Murphy and Riley (1962) method by reading the optical densities within 30 minutes of reagent addition to the sample.

In the best early phosphate surveys in Chesapeake Bay, Newcombe and Lang (1939) used a manual technique apparently similar to that described by Wattenberg (1937). Care was taken to control color development and salt error making this data set highly reliable for dissolved inorganic phosphate.

Analytical methods for nitrate in saline waters first utilized reduced strychnine with 8 to 24 hour development. Then diphenylbenzidine was employed as the nitrate reagent because it gave improved color stability. Transition to the current methods involved reduction of nitrate to nitrite by copper-hydrazine (Mullin and Riley, 1955), amalgamated cadmium (Morris and Riley, 1963) and copper-cadmium (Wood et al., 1967). The nitrite is then quantitated by the method of Bendschneider and Robinson (1952).

Historical data for ammonium ion and silicate have poor general reliability.

Krogh (1934) suggested a distillation method for ammonium in water and air. It was tedious and difficult to accomplish in the field without loss or contamination by degradation of organic compounds. Riley (1953) suggested a distillation-colorimetric method utilizing indophenol. The most widely accepted current method was described by Solorzano (1969). It is a direct colormetric technique which requires three reagent additions and development time of 20 minutes at 50°C (McCarthy et al., 1977).

Silicate determination is based on formation of a heteropoly acid with molybdate and sulfuric acid. Obviously, samples cannot be stored in glass prior to analysis and should not be filtered using glass scintered supports and filters. Phosphate and iron may interfere, which is probably not significant for open ocean but may be important in Chesapeake Bay during seasons of low silicate and high phosphate and iron. Although the earliest procedures were simple, and salt errors existed, the color could be difficult to compare visually if faint. Robinson and Thompson (1948) attempted to standardize silicate procedures. Armstrong (1951) suggested an improved approach based on Strickland's careful investigation of the properties of silicomolybdic acid (see Strickland, 1952). Mullin and Riley (1955) investigated the activity of five reductants and recommended metolsulphite solution as reductant. Salt error in full seawater was found to be -9.8 percent of standard. This method obeys Beer's law up to 3 $mg \cdot l^{-1}$.

Table C-1 summarizes methods for phosphate, silicate, ammonium, and nitrate. These have undergone considerable modification in the last 50 years to improve precision, reliability and ease of handling. Limits of detection, however, have not improved greatly. In fact, laboratory notes of Newcombe claim detectability of 0.01 ug atom $P \cdot l^{-1}$ with manual optic comparisons as opposed to 0.03 ug atom $P \cdot l^{-1}$ for current spectrophotometric methodology. While skepticism has been expressed about the low limits of detection claimed by Newcombe, we note that concentrations that we observed in central Chesapeake Bay compare favorably with later observations taken by the Chesapeake Bay Institute in the same areas. Questions about lower limits of detection thus do not seriously affect our conclusions about historical changes in concentrations that we reach later in this chapter.

Historical data for chlorophyll have poor reliability before the early 1950's. Furthermore, chlorophyll determination has become routine only in the last 20 years; thus few early data exist for comparative use.

Harvey (1934) was among the first to measure pigments as a relative assessment of size of phytoplankton standing stock. Samples were extracted in acetone and compared to an arbitrary standard containing potassium chromate and iodine sulphate. Reliable chlorophyll techniques were first developed in the early 1950's (Richards with Thompson, 1952), although it was really much later that it was appreciated that chlorophyll degradation products, such as phaeophytin may be present and give a false indication of the presence of active chlorophyll (e.g. Yentsch and Menzel, 1963). Thus, earlier (1950 to mid-1960) chlorophyll values would tend to be erroneously high because corrections for phaeophytin were not reliably applied. Furthermore, according to Vollendweider (1969, p. 21), "chlorophyll *a* values calculated on the basis of the earlier Richards with Thompson equations are probably affected by an error of about +25%," due to adjustments in their original equations. Accordingly, it is clear that with time, analytical

Table C-1. Summary of modification in analytical methods for nutrients in sea water.

Ion	Method	Limit of Detection*	Precision	Remarks
$PO_4^{\equiv}$	Harvey 1948	0.03 ug at/1	± 0.02 ug at/1	Fades-Salt error 10-20% between distilled & sea waters
	Wooster & Rakestraw 1951			Color unstable with temperature
	Murphy & Riley 1958		± 0.5%	Ascorbic acid reductant-color/stable 60h, 4% salt error, 24h color development.
	Murphy & Riley 1962	0.03 ug at/1	± 0.5%	Antimony gives 10 Min color development Salt error ± 0.7%
$SiO_3^{=}$	Robison & Thompson 1948	0.07 ug at/1	± 5%	$PO_4^{\equiv}$ & Fe interference
	Armstrong 1951	0.1 ug at/1	± 3%	Salt error minimum. $PO_4^{\equiv}$ & $AsO_4^{\equiv}$ interference
	Mullin & Riley 1955	0.1 ug at/1	± 0.5%	P, Ge, V may interefere. Salt error up to 10%
NH_4^+	Krogh 1934	0.18 ug at/1	± 0.14 ug at/1	Distillation & titration
	Riley 1953	0.10 ug at/1	± 0.07 ug at/1	Distillation & colormetric determination of Indophenol
	Solorzano 1969	0.10 ug at/1	± 0.05 ug at/1	Direct colorometric determination of Indophenol
NO_3^-	Mullin & Riley 1955	0.02 ug at/1	± 2%	Cu catalyst with hydrazine reduction of NO_3^- to NO_2^-. Marked salt effect.
	Morris & Riley 1963		± 2%	Amalgamated Cd column efficiency 91 ± 1%. No salt error.
	Wood et al. 1967	0.05 ug at/1	± 4%	Cu-Cd column efficiency 99 ± 1%.
	Armstrong 1963	<0.25 ug at/1	± 0.4 (SD)	UV spectrophotometry.

*In the hands of a competent analyst using the best available colorimetric detection devices available at the time.

EPA-287 (Cin.)
(4-76)

Table C-2. Brief generic description of detectors used for the quantitative determination of nutrients in sea and estuarine waters.

Type	Description[1]
Color Comparator	Colors are matched visually with standard solutions using a standard series of colored solutions or discs, a duplication method (standard curve), a dilution method, or a balancing method. Subject to error in interpretation of human eye. No longer in wide use except in field kits (e.g. Hach Instruments).
Visual Filter Photometer	Artificial light source is coupled with visual null-balancing. Better than color photometry. Subject to error in interpretation of human eye. No longer in wide use.
Photo-electric Filter Photometer	Spectral filters, artificial light sources and photovoltaic cells are generally used in the optical system; electrical null-balancing is not employed. Better than color comparator or visual filter photometer. Early units suffered from primitive electronics, but were nonetheless precise. Color filters may have reduced precision by missing peak spectral absorbance of color. Short light paths in some instruments also reduced precision. Modern equivalents are still used, however--e.g., the "colorimeter" in an "AutoAnalyzer" by Technicon Instruments.
Spectrophotometer	Prism or grating used to control color, artificial and stable light is employed, and sensitive phototubes are used as detectors. Generally are used today, and are most specific, precise, and accurate. Exact wavelengths can be dialed in to obtain reading at peak spectral absorbance. Allow reading in UV or infrared where absorption may be stronger than in visual. If a long cell path is employed, generally is the most precise way of doing most nutrient determinations.
Fluorometer	Not actually a "colorimetric" instrument, but offers promise of enhanced sensitivity once appropriate chemistries are developed. Has been used by some for NH_4^+ determination in marine waters.

[1] See Barnes, 1959, for a more thorough discussion of instruments, sensitivity, range and accuracy.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUS-TRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

determination of chlorophyll has resulted in lower values. This means that increases observed in chlorophyll in the historical record during this study are probably real.

Chronology of colorimetric detection device use. The determination of most non-conservative substances in seawater usually involves "colorimetric" techniques. Nutrient (NO_2^-, NO_3^-, etc.) concentrations in seawater have always been determined principally in such a manner. Colorimetric technology has improved substantially since nutrients were first measured in sea and estuarine waters. This improvement would improve detection limits for procedures when most other factors (e.g., reaction chemistry) have remained the same, since the overall sensitivity of any method depends on both chemical and detection factors.

There are some excellent published reviews on the subject of apparatus and analytical methods of oceanography (Barnes, 1959; Riley, 1975), so it makes little sense to repeat such information exhaustively here. However, we have produced a Table (C-2) which gives a brief generic description of the instruments employed in color detection and a Table (C-3) which gives an approximate chronology of use of these instruments.

Table C-3. Approximate chronology of extensive use of "colorimetric" detectors for nutrient analysis in sea and estuarine waters.

Year	Color Comparator	Visual Filter Photometer	Photoelectric Filter Photometer	Spectrophotometer
pre 1930	x	x		
1930-1940	x	x		
1940-1950	x	x	x	
1950-1960			x	x
1960-1970	x*		x+	x
1970-1980	x*		x+	x

*Primarily as field kits (e.g. Hach or Helige Instruments)
+Primarily as components of automated analysis systems

UPPER CHESAPEAKE BAY

The earliest measurement of water quality in the upper Bay that we encountered [excluding the early observations of Cumming (1916) and Olson, Brust and Tressler (1941) in Baltimore Harbor] were made on three dates during August and September, 1938 (our data base code number M022005).

Temperature, salinity, and concentrations of dissolved oxygen and phosphorus were measured at 3 to 8-m depth intervals at stations from near the mouth of the Patuxent River (discussed in a later part of this chapter) to near Annapolis or Sandy Point. From August 1949 through May 1951 the Chesapeake Bay Institute (C.B.I.) conducted a series of cruises the length of the Bay and measured phosphorus, chlorophyll and turbidity, in addition to physical parameters. Hires, Stroup and Seitz (1963) and Stroup and Wood (1966) prepared graphical summaries of the data collected on those cruises, which have also been published in C.B.I. data reports 1-10 and are in the C.B.I. data base. From 1950 through 1952, Mr. James Van Engle measured concentrations of phosphorus over four oyster bars in the Fishing Bay area. Those unpublished data were made available to us through the Annapolis Field Office of the U.S. E.P.A. and have been entered into our data base (MO22017). Between February 1964 and April 1966, C.B.I. collected data on nutrients in the upper Bay including the three forms of inorganic nitrogen. Chlorophyll and attenuation of light were also measured in addition to physical parameters. Tabular presentations of the 1964-1966 C.B.I. data are available (Whaley, Carpenter and Baker, 1966; Carpenter, Pritchard and Whaley, 1969) and the data are in the C.B.I. data base. From April 1965 through January 1977 the Chesapeake Biological Laboratory (CBL) conducted a study of the upper Bay during which chlorophyll and turbidity were measured in addition to the physical parameters. These results are summarized by Flemer (1970), with emphasis on the distribution of chlorophyll *a* and Secchi disc depth. Also included were estimates of primary production and the lateral variation of chlorophyll *a*. These data have been incorporated into our data base (MO00295). During 1967 and 1968 the Federal Water Pollution Control Administration (now E.P.A.) conducted a number of water quality surveys in the upper Bay and tributaries. These have appeared as several data reports; data report No. 4 (Anon., 1968), data report No. 12 (Marks and Villa, 1969) and data report No. 23 (Anon., 1971b) (MO22009 in our data base). During the same period the State of Maryland studied the Elk River and the C & D Canal (Brunoric, 1968) (MO22011 in our data base). Slightly later, 1969 through 1971, E.P.A. again assessed the water quality of the upper Bay (Anon., 1971a) (MO22006 in our data base). The E.P.A. studies generally included all the major nutrients, chlorophyll, D.O. and physical parameters. Major trends during 1968 through 1971 were summarized by Clark, Donnelly and Villa (1973) (MO22007). During 1969 to 1971 C.B.I. again conducted a series of Bay-wide cruises. Nutrients and chlorophyll (Taylor and Grant, 1977) and physical parameters (Taylor and Cronin, 1974) were reported separately in tabular form. The data are also in the C.B.I. data base and are reported on in part elsewhere in this chapter (Middle Bay and Lower Bay).

There have also been a number of studies dealing with phytoplankton in the upper Bay and phytoplankton-nutrient relationships for which a data base exists that we did not acquire because it duplicates more readily available data (e.g., Loftus, Subba, Rao and Seliger, 1972; Tyler and Seliger, 1978). Clarke, Donnelly and Villa (1973) reported trends of increasing chlorophyll and nutrient concentrations in the upper Bay based on the data in Anon. (1971a,b,c) (MO22006). Clarke et al. (1973) commented on excessive algal blooms, including changes in species composition (a shift toward blue-green algae in some tributaries). They also noted historical increases in concentrations of phosphorus and the possibility that nitrogen was becoming the limiting nutrient (based on very low concentrations during periods of maximum algal blooms). Salas and Thomann (1976) showed historical changes in concentrations of chlorophyll and nitrogen to be relatively greater than those of phosphorus. Their figures and analyses were based on vertically averaged concentrations *over the length of the Bay*, a serious flaw as processes of nutrient uptake and remineralization are quite different in the turbulent upper Bay and the two-layered lower Bay (Webb, 1980).

We have reviewed the same data base used by Salas and Thomann (1976) except for the period after tropical storm "Agnes." In addition we used the data reported by Taylor and Grant (1977) for the period 1969-1971 and the data for 1966 and 1967 reported by CBL (M000295). Our analysis included stations from C.B.I. station 858D and upstream (aproximately from Annapolis up).

When only upper Bay data are included, the increased concentrations of phosphorus during May through August in later years are apparent (Fig. C-1). In the studies by C.B.I. in 1949-1951 and 1964-1966, concentrations of PO$_4^{-3}$-P were generally about 0.2 ug-at 1^{-1} or lower during May through August. In later years, 1969-1971, higher maximum concentrations were observed, 0.5 to over 1.0 ug-at 1^{-1} during the same months (Fig. C-1). During the rest of the year, phosphorus concentrations, while variable from year to year, show no trends of increase (Fig. C-1).

The upper Bay has changed from a pattern of maximum phosphorus concentrations in the spring and fall, with a summer minimum, to relatively uniform concentrations all year.

In contrast, the concentrations of nitrate plus nitrite-N, the only forms consistently measured over time, have not changed in the upper Bay, except possibly during November (Fig. C-2). Minimum concentrations of nitrogen occurred in September (< 8 ug-at 1^{-1}, Fig. C-2). The seasonal pattern for NO_3^- + NO_2^- - N is fairly typical for the entire Bay, although minimum concentrations may occur earlier down-Bay (see later parts of this chapter).

The evidence for increased concentrations of chlorophyll *a* is not nearly as clear (Fig. C-3). Although concentrations never exceeded 10 ug 1^{-1} during the 1949-1951 studies by C.B.I. (Stroup and Wood, 1966), no measurements of chlorophyll *a* were made during August and September of that study. By 1965, maximum concentrations of 55 to 80 ug 1^{-1} were observed in the upper Bay during July and September. The concentrations reported during May through August for 1969-1971 by C.B.I. (Taylor and Grant, 1977) were slightly higher than previously observed for those months. The concentrations reported by E.P.A. (Anon., 1971a,b,c) were considerably higher during the same period. We were unable to resolve the discrepancy between these two sets of data. It should be noted that although the sampling was less regular in the E.P.A. study, the spatial coverage was greater and more samples were taken on most dates than during the C.B.I. studies. The maximum chlorophyll *a* concentrations during the summers of 1966 and 1967 reported in the studies by CBL (M000295) (Fig. C-4) were somewhat higher than those reported by C.B.I. during 1964-1966 (Fig. C-3). Minimum concentrations were similar in the two

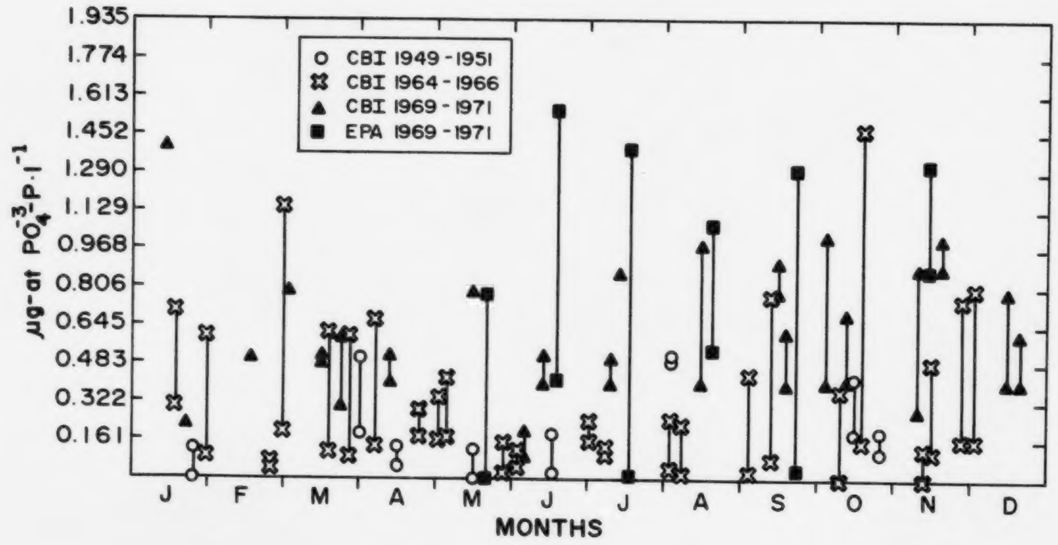


Figure C-1. Ranges of concentrations of orthophosphate-phosphorus observed during studies of the upper Chesapeake Bay (Susquehanna flats to Annapolis).

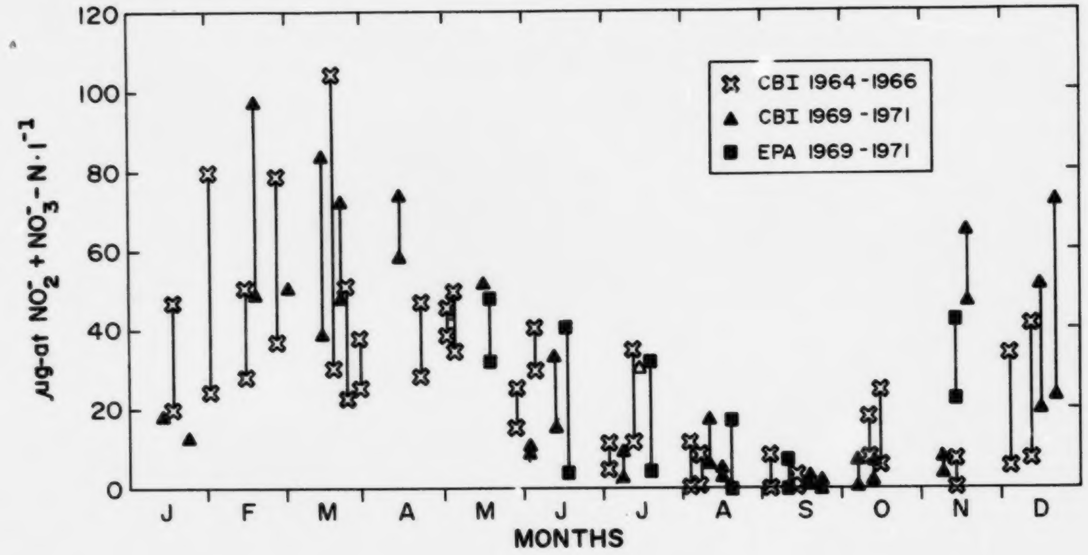


Figure C-2. Ranges of concentrations of nitrate plus nitrite-nitrogen observed during studies of the upper Chesapeake Bay.

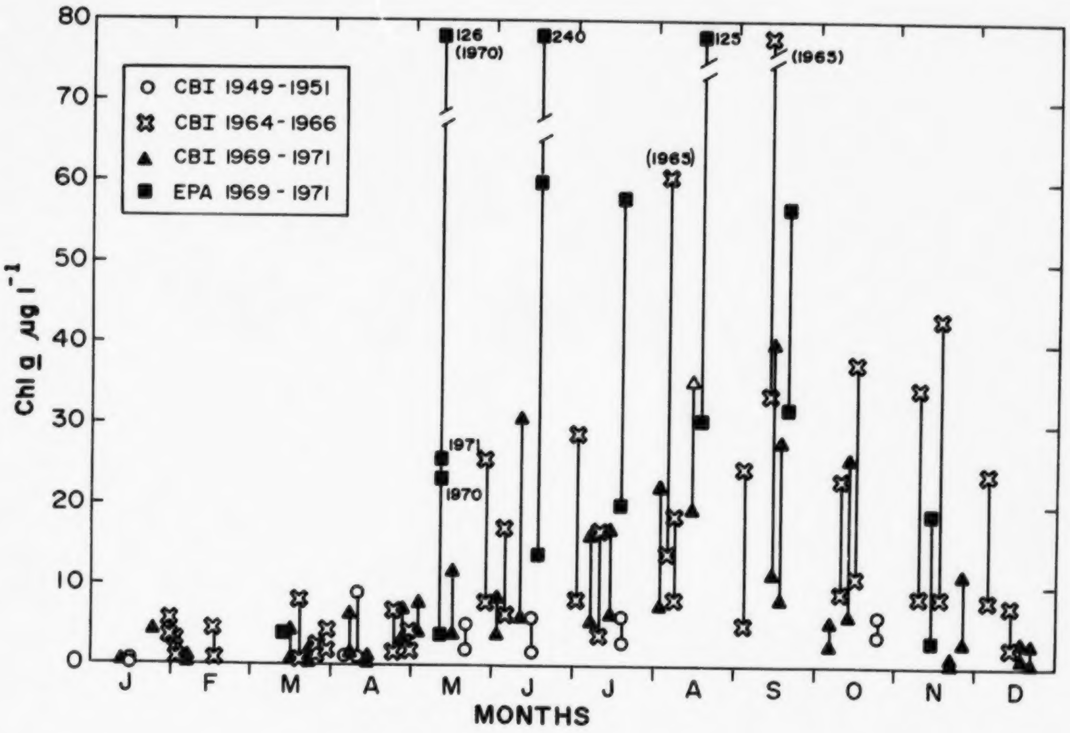


Figure C-3. Ranges of concentrations of chlorophyll a observed during studies of the upper Chesapeake Bay.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

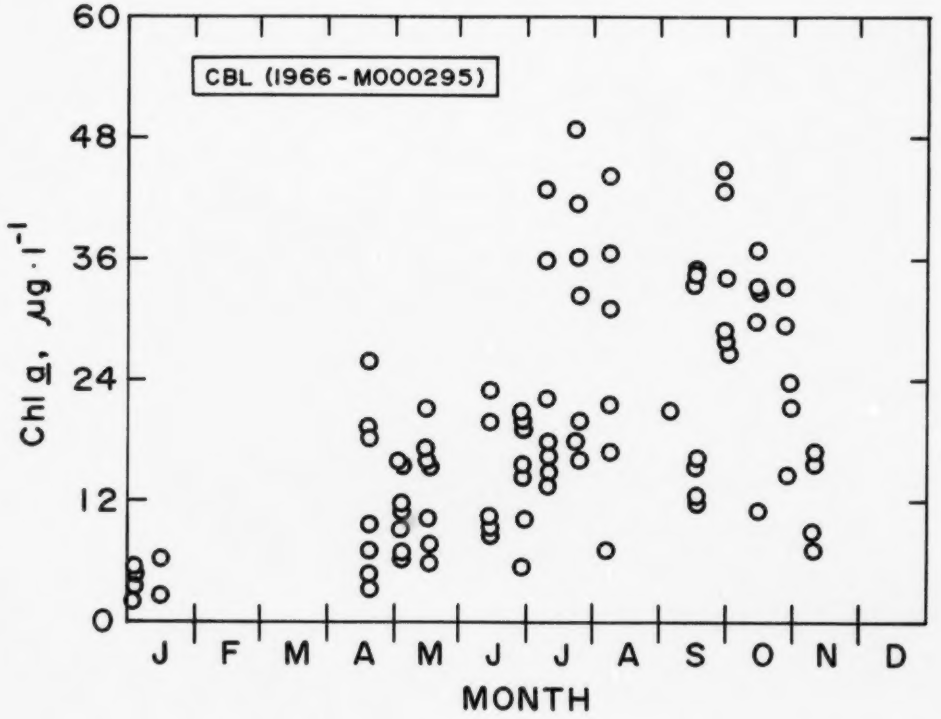


Figure C-4. Maximum chlorophyll a concentrations during summers of 1966 and 1967 reported in the studies by the Chesapeake Biological Laboratory.

For the purpose of examining trends, data for parameters which have the longest records were selected.

Secchi depth (Fig. C-5) was generally in the range 1.5 to 4 m in the mid-1930's and the early 1960's. The maximum value of 4.6 m was recorded in the 1970's.

Dissolved phosphate was comparable at all depths from 1936-1951, with values from undetectable to 1.3 ug atom$\cdot$l^{-1} (Fig. C-6 to C-8). By 1964-1966 maximum values increased to 2 ug atom$\cdot$l^{-1} and by the mid-1970's values of 2.5 ug atom$\cdot$l^{-1} were observed.

Chlorophyll *a* data show some increases in the mid-Bay between 1951 and 1964-1966. Peak values in the euphotic zone (upper 10 m) are less than 25 ug$\cdot$l^{-1} (Fig. C-9). The highest values were observed in the deep water, usually in winter or spring. Peak values were 28 to 45 ug$\cdot$l^{-1}. Occasionally, the data for surface waters show increased chlorophyll *a* near the Potomac River mouth. Since this is not a regular feature, we cannot conclude that the Potomac is a major source of phytoplankton for the mid-Bay. Most chlorophyll *a* results from phytoplankton growth in the Bay itself.

If *in situ* phytoplankton growth were increasing in the mid-Bay region during 1936-1978, maximum pH values for surface waters might also increase with removal of greater amounts of CO_2 in daylight hours. The pH data in Figure C-10 do not show increases in maximum values. Most pH values range 7.8 to 8.5. In contrast the pH of water 20 to 30 m deep is usually 7.4 to 7.9 probably due to respiratory CO_2 production (Fig. C-11). Thus although photosynthetic and respiration affect the vertical pH gradient there is no clear indication of increasing pH in surface waters over time due to enhanced photosynthesis. However, note that the buffering capacity of sea water makes pH a poor indicator of changes in trophic state unless very high values coincide with high rates of primary production.

Phosphorus probably limits biomass in spring when inorganic nitrogen is abundant (Taft et al., 1975; Taft and Taylor, 1976a,b). However, there are too few data to establish clearly a limiting nutrient in other seasons, Flemer and Biggs (1971) have noted that "the suspended particulate organic material in the lower study area is suffering a relative loss of nitrogen with respect to carbon." A graph of the Secchi depth and phosphorus data (Fig. C-12) reveals an inverse relationship. But since most phytoplankton species can store phosphorus beyond immediate requirements, phosphorus limitation of the phytoplankton biomass cannot be established solely from this graph. Additional information about the physiological condition of the organisms such as alkaline phosphatase activity would have to be used (Taft et al., 1977). Such information is not available in the historical data base.

The range of dissolved oxygen values for surface waters is comparable in the earliest and latest data sets available (Fig. C-13). Oxygen concentrations in the deep water, however, seem to be depressed for longer periods in summer and over wider regions of the mid-Bay. Newcombe and Horne (1938) and Taft et al. (1980) discuss oxygen depletion. The oxygen demand

EPA-287 (Cin.)
(4-76)

studies. If the stations from the CBL study that we did not include in Figure C-4 (Appendix B) were included, the range of chlorophyll a concentrations would be further increased. Based on the C.B.I. data alone, one would not conclude that concentrations of chlorophyll a have increased in the upper Bay between 1964 and 1971. Increases are indicated between 1949-1951 and 1964-1966 for the months of May, June, July and October, with no basis for comparison for August, September and November due to the paucity of data in 1949-1951.

Based on the conceptual model presented by Webb (1980) (shown later in Chapter C), we propose the following sequence. Between 1951 and 1964, gradual increases in nutrient input led to moderate increases in algal standing stock, but no changes in concentrations of inorganic nutrients. Both nutrients (N and P) may have played a part in limiting algal biomass during this period. Between 1966 and 1969, continued increases in nutrient input caused further increases in algal biomass, particularly in the form of intense local blooms detected by the greater spatial intensity of the E.P.A. and CBL sampling programs. Algal species composition changed, as reported by Clark, et al. (1973), and orthophosphate-phosphorus, now present in excess, remains in relatively high concentrations in the water throughout the summer.

The seasonal pattern of phosphorus now closely resembles the pattern reported for the middle-Bay and lower Patuxent River in the late 1930's by Newcombe and Brust (1940). The conclusions of Salas and Thomann (1976) concerning limitation by phosphorus in the upper Bay thus appear to be incorrect, in contrast to those of Clark, et al. (1973) who claim that nitrogen is presently the limiting nutrient in the upper Bay. Jaworski (1980) favors phosphorus limitation based on N:P ratios of the inputs. That concept, however, fails to consider the possibility of denitrification (Kaplan, et al., 1978; McElroy, et al., 1978; Elkins, 1978; Elkins, et al., 1980) or of differential rates of resupply from the sediments (Nixon, 1980; Boynton, Kemp and Osborne, 1980; Webb and D'Elia, 1980; Bray, et al., 1973). Since N:P ratios of inputs may vary seasonally, with runoff, it is also possible that there can be temporal variation in limiting nutrient. Thus, averaging N:P inputs over an annual cycle could be misleading.

In summary, increases in nutrient input have led to increases in phytoplankton standing stocks in the upper Bay and seasonal increases in phosphorus concentration. There may have been a shift from past limitation of phytoplankton production by scarcity of phosphorus in the summer months, to present limitation by nitrogen or light or both. The composition of the phytoplankton has changed, with blue-green algae now commonly present.

MIDDLE CHESAPEAKE BAY

Data for the middle Bay (Chesapeake Beach to Smith Point) are available from Newcombe (1940), Newcombe and Brust (1940), and Newcombe and Lang (1939) on phosphorus for 1937-1938. The C.B.I. cruises in 1949-1951, 1964-1966, 1969-1971, and 1972-1978 provide nutrient, chlorophyll a, pH and dissolved oxygen data. Secchi depth, pH, silicate and dissolved oxygen are available from the CBL data base.

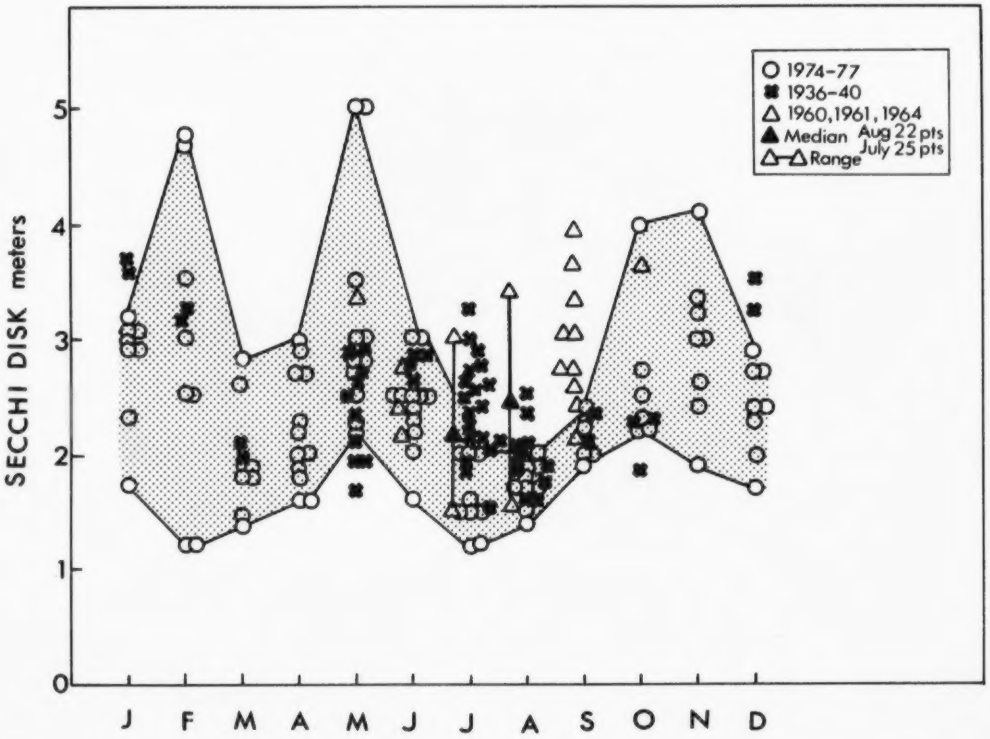


Figure C-5. Secchi depth (m) at mid-Bay during selected intervals of time plotted on an annual time scale.

EPA-287 (Cin.)
(6-76)

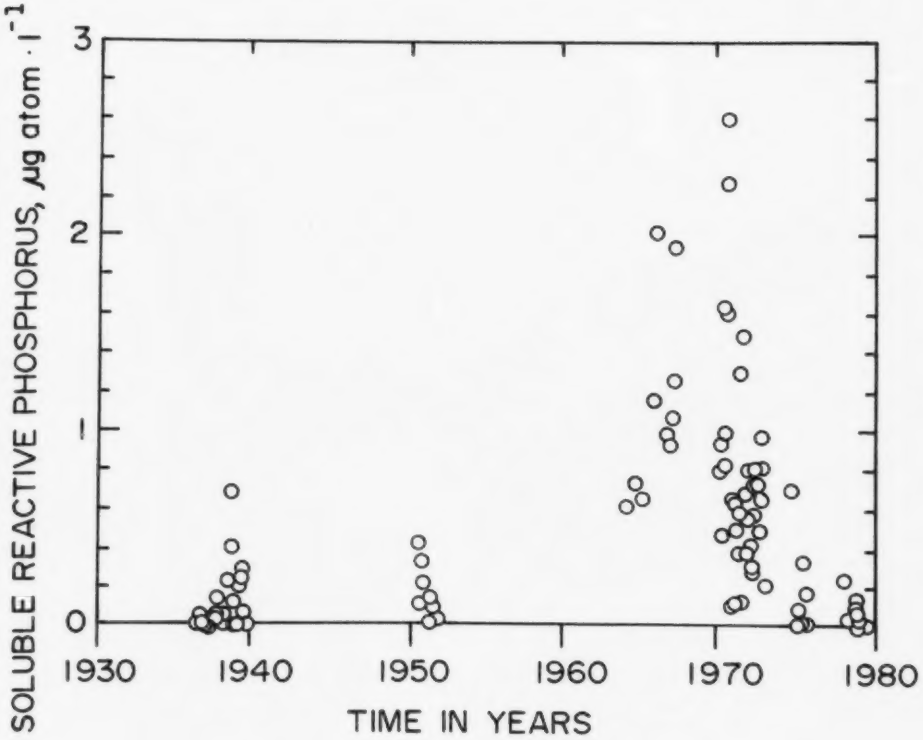


Figure C-6. Monthly mean concentrations of PO_4^{-3}-P in the surface 10m at mid Chesapeake Bay as a function of time.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD, BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

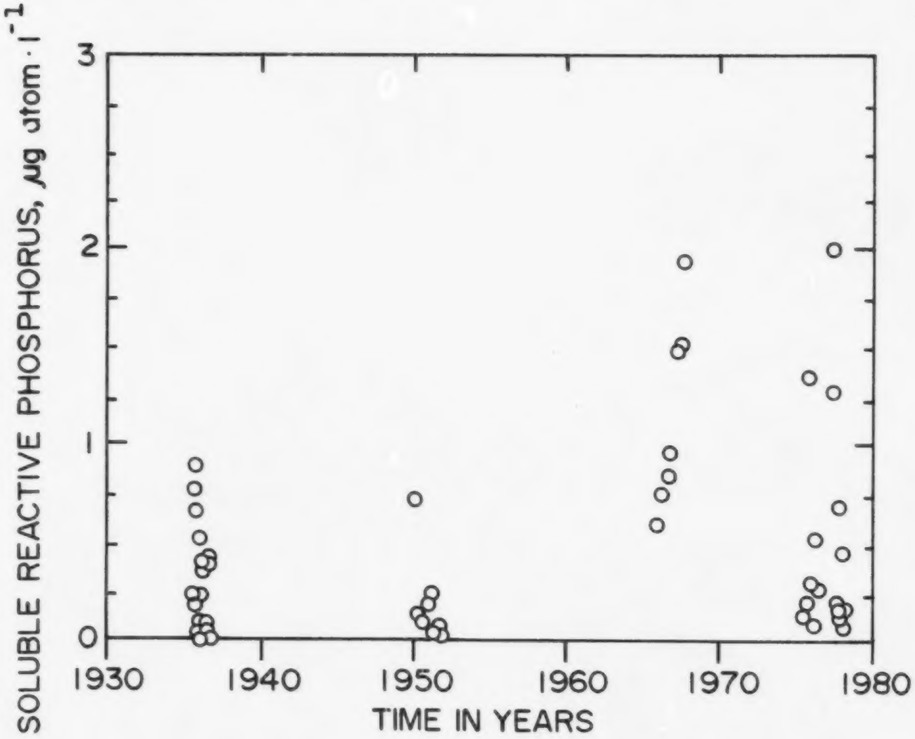


Figure C-7. Monthly mean concentrations of PO_4^{-3}-P at 10-20m depth at mid-Bay as a function of time.

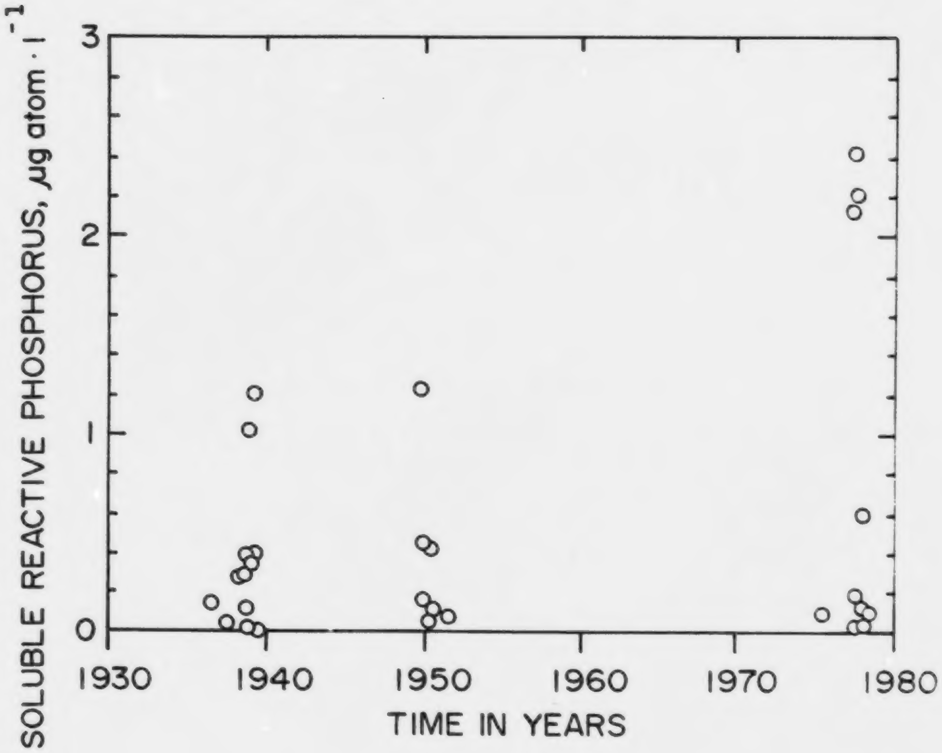


Figure C-8. Monthly mean concentrations of PO_4^{-3}-P at 20-30m depth at mid-Bay as a function of time.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD; BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
EPA-287 (Cin.)
(4-76)

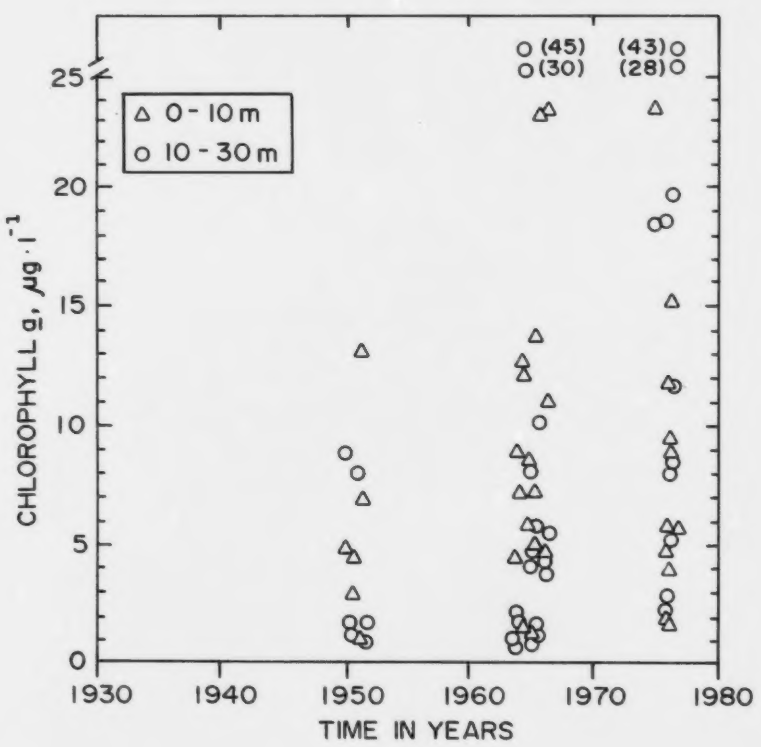


Figure C-9. Concentrations of chlorophyll a at 0-10m and 10-30m depth at selected (by availability of data) intervals of time.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin)
(3-76)

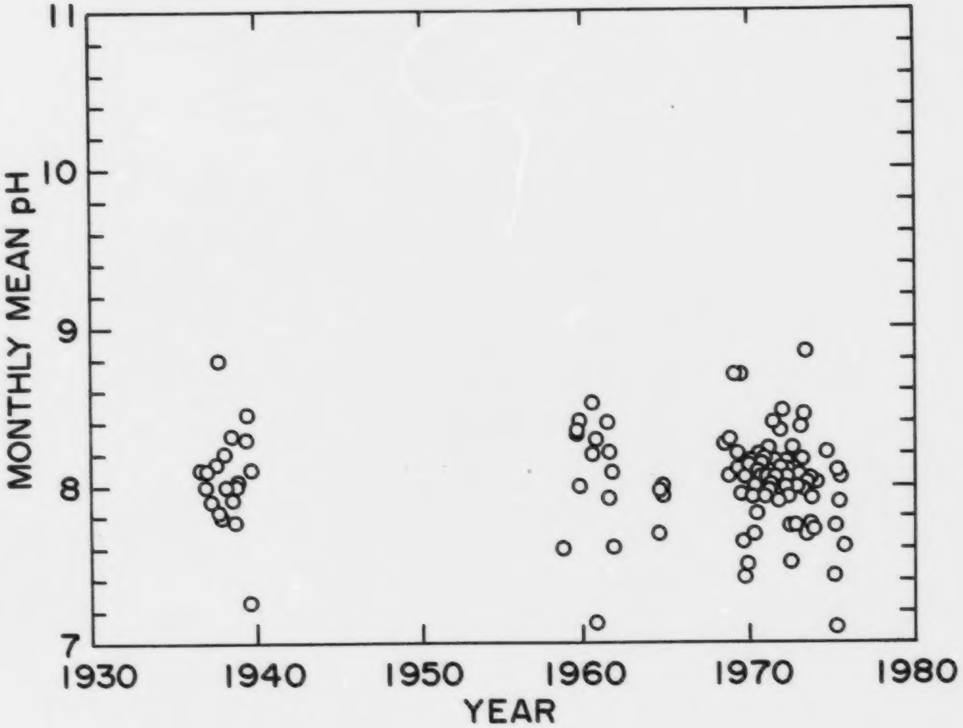


Figure C-10. pH of surface waters at mid-Bay as a function of time.

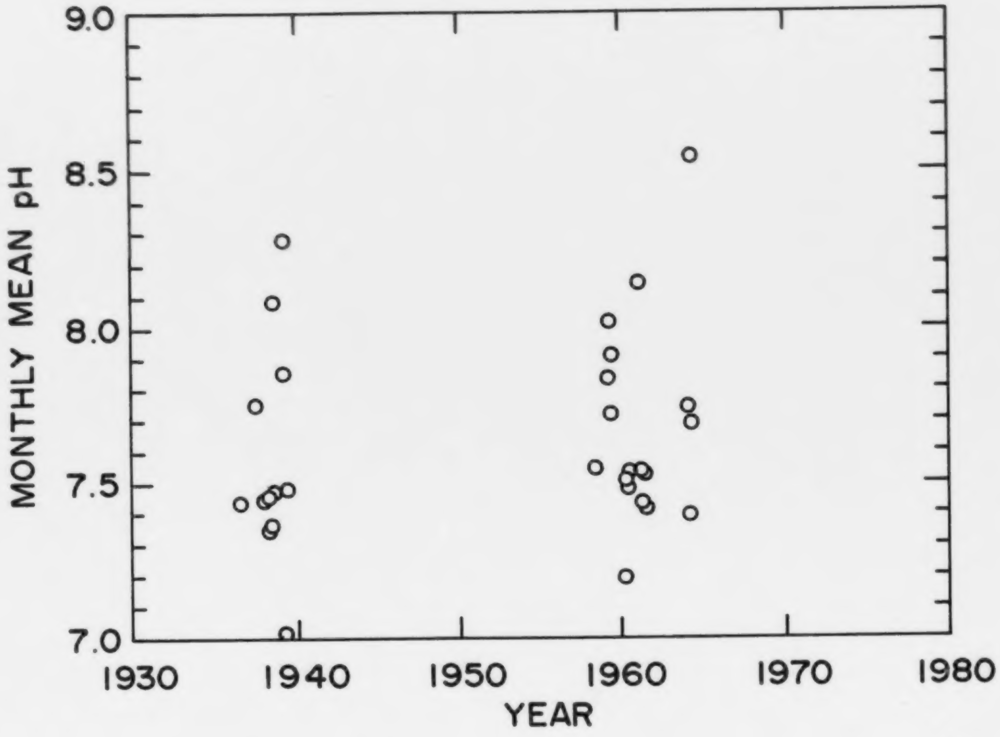


Figure C-11. pH of bottom waters at mid-Bay as a function of time.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD: BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA-287 (Bmo)
(4-76)

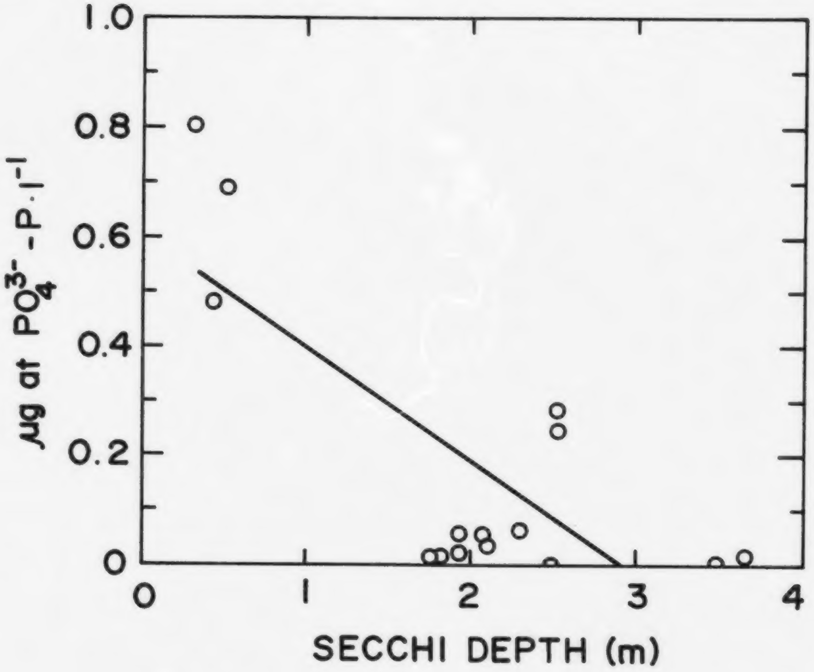


Figure C-12. Regression of phosphorus concentration versus Secchi depth at mid-Bay (all data in our data base).

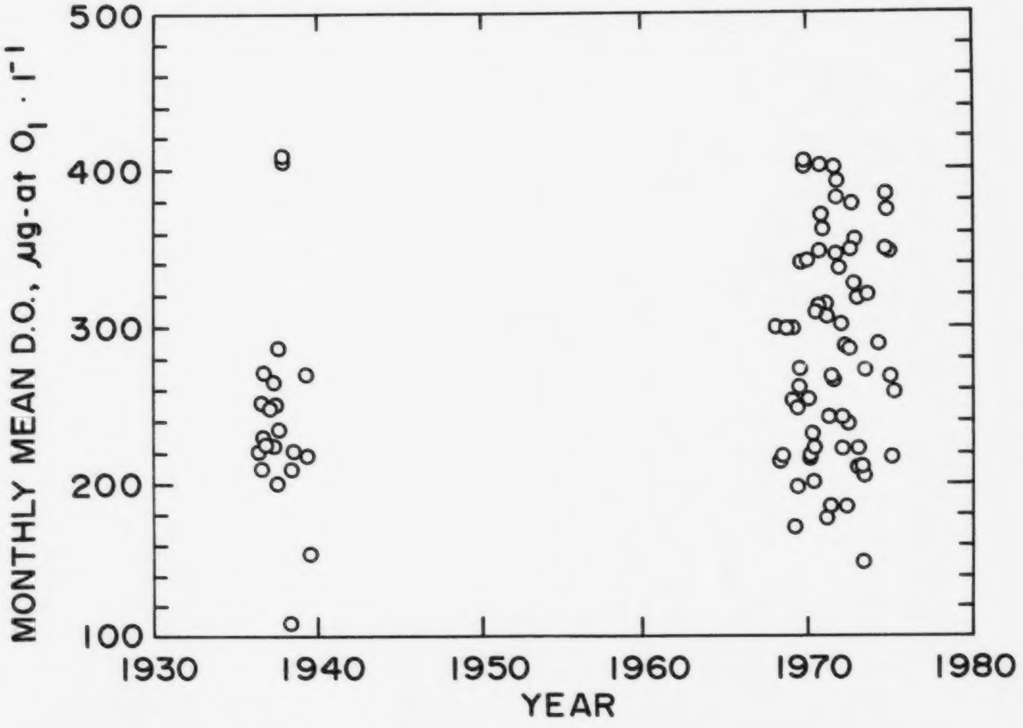


Figure C-13. Daytime concentrations of dissolved oxygen in surface waters at mid-Bay during two selected time intervals.

results from accumulation of algal organic material in the deep water and on surface sediments. When the water column is sufficiently stratified, oxygen is removed from the lower layer faster than it is replenished from the surface. Thus, in wet years oxygen depletion should be more exaggerated than in dry years. Unfortunately, the data base is not complete enough to test this hypothesis.

The data for nitrogen are least complete. The annual trend is for nitrate to be the dominant inorganic form in winter and spring, ammonium in summer and nitrite in fall. Long term trends cannot be defined at present. This is in part because sources are different for the various forms of dissolved combined nitrogen. The spring freshet contributes nitrate from groundwater and snow melt in the Susquehanna drainage basin (Carpenter et al., 1969). Little of this nitrogen appears to be utilized in the upper Bay because ammonium from planktonic and benthic regeneration is abundant. McCarthy et al. (1975, 1977) have shown that at ammonium concentrations greater than 1.0-1.5 uM, nitrate uptake by phytoplankton is minimal. The nitrite maximum often observed in fall (McCarthy et al., 1977) seems to result from oxidation of ammonium accumulated below the pycocline during summer stratification. However, rates and sites of oxidation are poorly understood at present.

Silicate showed comparable ranges in 1937-1938 and the early 1970's (Fig. C-14). Annual variations are 0 to 60 ug atom·l^{-1} but no long term trend is discernable.

In the middle Bay, as elsewhere, long-term residents report greater frequencies of brown water blooms. In the summer of 1979, offensive odors, similar to dead fish but with no fish evidenced, were reported on several occasions and noticed by one of us (DRH).

In summary, the middle Bay appears slightly richer in phytoplankton and phosphorus now than in the mid-1930's. The greatest change was from 1951-1965. The magnitude and duration of deep water anoxia may have increased since 1965, but since 1964-1966 were relatively dry years, they might be expected to have had more favorable conditions for deep water reoxygenation. Thus 1964-1966 is not an average period, making it a poor base line reference.

LOWER CHESAPEAKE BAY

Data for the lower Bay (Smith Point and south) are available from the C.B.I. cruises in 1949-1951 on phosphate and chlorophyll, and in 1967 on chlorophyll and in 1969-1971 on inorganic nitrogen, phosphorus and chlorophyll. Some data on nutrients and chlorophyll for June of 1972 are available from Smith, et al. (1976). Chlorophyll a measurements are also available graphically from Patten, Mulford and Warriner (1963) for the early 1960's and from Fleischer, et al. (1976) for the mid-1970's. Sufficient data exist to establish trends for chlorophyll a and orthophosphate-P.

Orthophosphate concentrations were generally below 0.2 ug-at l^{-1} during January through April in the early 1950's rising to maxima of 0.8 to

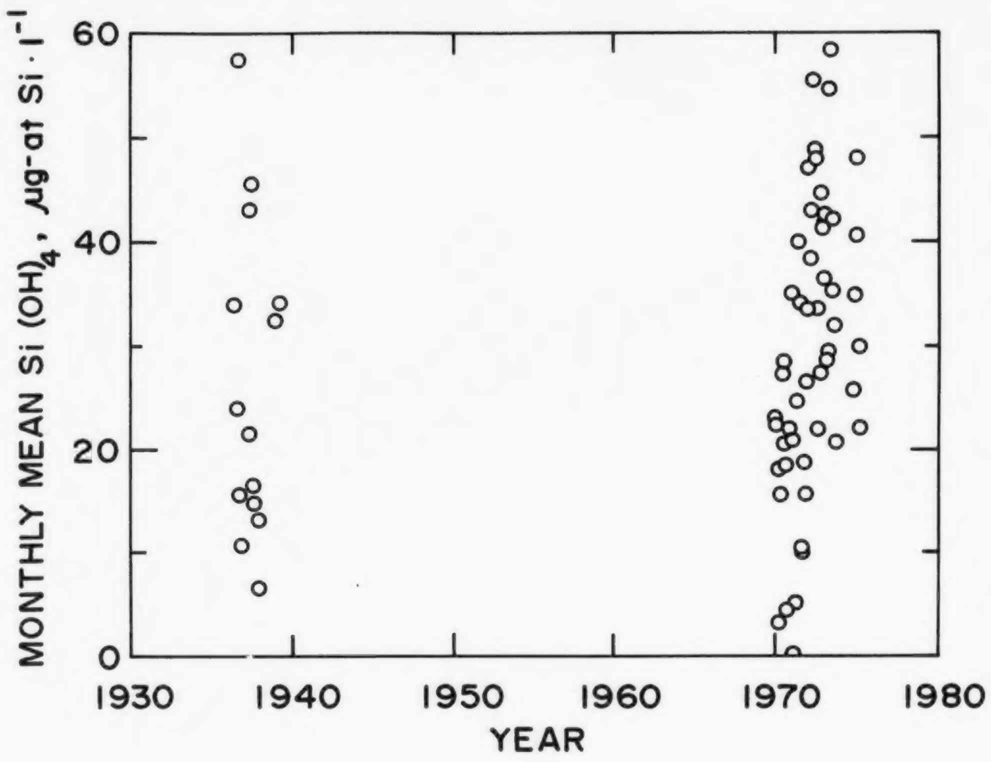


Figure C-14. Silicate concentration in surface water at mid-Bay at selected (based on available data) times.

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

1.0 ug-at l^{-1} in mid-to late summer (Fig. C-15). In 1969-1971 concentrations of orthophosphate were somewhat higher, 0.3 to 0.7 during the same period (Fig. C-15). Maximum concentrations in the summer and fall are occasionally, but not regularly, higher.

Nitrogen ($NO_3^- + NO_2^- + NH_4^+ - N$) has not been measured long enough to establish trends in the open lower Bay. The two-year data from the C.B.I. cruises establishes a clear pattern for $NO_3^- + NO_2^- - N$ maxima of 12 to 25 ug-at l^{-1} in March and April falling to low summer values of generally less than 1.0 ug-at l^{-1} by June. Occasionally higher values are observed during August and September when concentrations begin to increase again. McCarthy, Taylor and Taft (1977) provide a description of the seasonal patterns of nitrogen concentration and use by phytoplankton.

Because nitrogen is most often the limiting major nutrient in higher salinity areas of Chesapeake Bay (Webb, 1980), one would not expect the observed increases in phosphorus to lead to increased algal stocks. Concentrations of chlorophyll *a* have not increased greatly, if at all, over the period of record (Fig. C-16). There is a definite spring maximum in some years of up to 22 ug l^{-1} of chlorophyll *a*. During the rest of the year, concentrations are generally below 13 ug l^{-1}.

The early C.B.I. data often show a chlorophyll maximum in the vicinity of Smith Point to below the mouth of the Rappahannock River which may occur at any time of the year. The chlorophyll maximum is sometimes associated with a variation (either an increase or decrease) in phosphorus. The depth profiles show a shoaling of the channel in that area which often marks the down-Bay limit of anoxic bottom waters. Low concentrations of dissolved oxygen do not normally occur in the Bay very far below Smith Point (the mouth of the Potomac River on the Virginia side), so that parameter has not been routinely measured except in the studies by C.B.I. The chlorophyll maximum might thus be caused by natural features of the Bay. An excellent baseline exists in the 1949-1951 data of C.B.I. for comparison with future data on chlorophyll.

The lower Bay has experienced increases in concentrations of phosphorus in recent years with an apparent effect on algal standing stocks. Recent measurements of primary production (or often productivity) are sufficiently different in method from those of Patten (1962) (Patten, et al. 1963) that direct comparisons cannot be made. We conclude, however, that the lower Bay remains relatively unperturbed.

CHOPTANK, CHESTER AND MILES RIVERS

The lower Choptank and Chester Rivers as well as Eastern and Fishing Bays were sampled for temperature, salinity, turbidity, dissolved oxygen, chlorophyll *a* and orthophosphate-P by C.B.I. in 1949-1951 (Hires, et al., 1963; Stroup and Wood, 1966). In 1964-1966 C.B.I. sampled the Chester and Miles Rivers for the same parameters plus the three major forms of inorganic nitrogen (Whaley, et al., 1966). A survey of the Chester River was conducted by E.P.A. during 1970 (Anon., 1971b) (MO22035). One can thus examine trends for the Chester River between 1950 and 1964-1966 and 1970, and for the Miles

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT HERE
3/8"
PAGE NUMBER
EPA-287 (Cin)
(4-76)

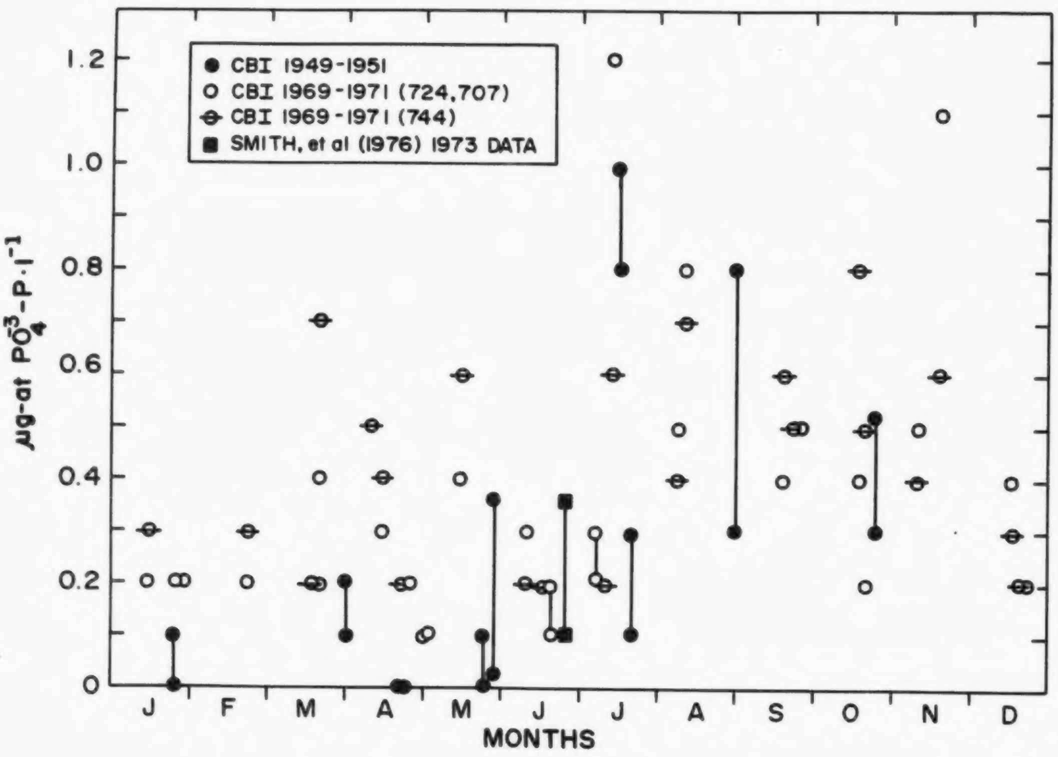


Figure C-15. Ranges of concentrations of dissolved PO_4^{-3} -P observed in the lower Chesapeake Bay (below Smith point) during various studies plotted as a function of season.

EPA Form 2360-4 (4-80)
TYPING GUIDE SHEET

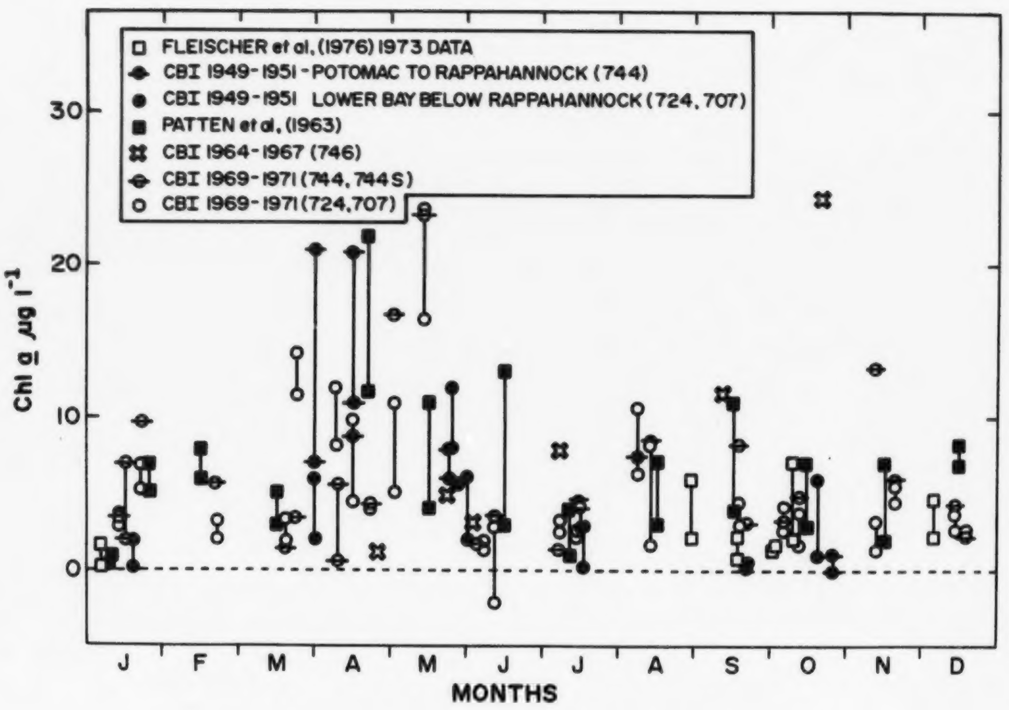


Figure C-16. Ranges of concentration of chlorophyll a observed in the lower Bay during various studies plotted as a function of season.

River and Eastern Bay between 1950 and 1964-1966. These are distant from large metropolitan areas, surrounded by rural areas and smaller communities.

The somewhat limited sampling in 1950 showed concentrations of chlorophyll *a* of 6 ug l^{-1} or less in the Chester, Choptank and Miles Rivers. Concentrations of PO_4^{3-}-P never exceeded 0.6 ug-at l^{-1}, with maximum concentrations observed in the late summer and fall. By 1964-1966, concentrations of chlorophyll *a* were only slightly higher in the Chester and Miles Rivers on the average, but occasional blooms of up to 45 ug l^{-1} were observed in the Chester. Concentrations of PO_4^{3-}-P were commonly in excess of 0.5 ug-at l^{-1}, and sometimes over 1.5 to 2.0 ug-at l^{-1}, with maxima still occurring in the fall and very low values in the spring. In 1970, concentrations of chlorophyll *a* of up to 29 ug l^{-1} were measured in the Chester River. Concentrations of PO_4^{3-}-P were commonly in excess of 2.0 ug-at l^{-1} during the summer months, but still apparently low in the spring.

During 1964-1966 concentrations of $NO_3^- + NO_2^-$ - N were typically 20 to 40 ug-at l^{-1} during the spring and generally below 10 ug-at l^{-1} during the summer in the Chester and Miles Rivers. Concentrations of nitrogen were generally highest near the confluence with Chesapeake Bay in summer months, often being less than 1.0 ug-at l^{-1} at upstream stations. The samples taken by E.P.A. in 1970 show no increase in nitrogen over the 1964-1966 values.

The middle eastern shore tributaries have experienced increases in concentrations of chlorophyll *a* and PO_4^{3-}-P, but not nitrogen. Chlorophyll *a* concentrations are generally 1.5 to 2.0 times higher than indicated by the earliest data, with occasional blooms of much greater concentrations. The mainstem of the Bay may be a major source of nitrogen for the middle eastern shore tributaries during the summer months.

MAGOTHY, SEVERN AND SOUTH RIVERS

The tributaries of the Bay in the vicinity of Annapolis were surveyed by C.B.I. in 1964-1966 (Whaley, et al., 1966) and by E.P.A. in 1967 (Marks and Villa, 1967) (M022036 in our data base), and again by E.P.A. in 1970 (Anon., 1971b) (M022035).

During the earliest studies, concentrations of chlorophyll *a* were often high, 30 to 52 ug l^{-1} near the mouths of the Severn and Magothy Rivers in 1964 and over 100 ug l^{-1} in the lower Severn in 1967. Concentrations of 40 to 50 ug l^{-1} were common in both the Severn and Magothy during 1967. During 1970, concentrations of chlorophyll *a* in the Severn River were similar to those observed in 1964-1966.

Concentrations of phosphorus were generally below 1.0 ug-at l^{-1} except during the late summer when concentrations ranged as high as 1.5 to 2.1 ug-at l^{-1}. Concentrations of PO_4^{3-}-P were somewhat higher during 1967 than during 1964-1965. By 1970 even higher concentrations of phosphorus were observed in the Severn River, up to 4.6 ug-at l^{-1}.

Nitrogen concentrations showed a pattern identical to that for the upper Bay (Fig. C-2) with no apparent increase with time. Concentrations of NO_3^- +

NO_2^- - N were frequently higher near the Bay than farther up the Severn and Magothy Rivers during the summer months in 1964-1966. Concentrations at upriver stations were similar to those downstream during 1970.

The patterns in the South River have paralleled those in the Severn and Magothy Rivers except that concentrations of both major nutrients and of chlorophyll *a* were somewhat lower than in the other two Rivers through 1967. The South River was not included in the 1970-1971 studies by E.P.A.

The Bay tributaries in the vicinity of Annapolis showed effects of enrichment in their lower reaches at the time of the first studies in 1964-1966. In more recent years, chlorophyll *a* concentrations have increased upstream, and maximum summer concentrations of PO_4^{3-}-P have increased throughout. The South River appears to have changed less than the Severn and Magothy Rivers. Like the eastern shore tributaries, the western shore tributaries may have received inputs of nitrogen from the Bay which were supplemented by landward sources by 1970.

PATUXENT RIVER

The data base for the Patuxent River estuary, which is the most historically comprehensive we have, begins in the period 1936 to 1940 with the studies reported by Newcombe and Horne (1938), Newcombe, Horne and Shepherd (1939), Newcombe and Lang (1939), Newcombe (1940), Newcombe and Brust (1940) and Nash (1947). The original data (M022004 and M022005 in Appendix B), which were not all found, are more extensive than reported in the literature. Even though the methods for some parameters were in early stages of development, others have changed little (Table C-1), and some, such as Secchi depth, while subjective, are unchangeable. Mihursky and Boynton (1978) recently reviewed the data base for the Patuxent estuary. Table C-4 reproduces their summary (their Table D-1). Mihursky and Boynton (1978) cited Stross and Stottlemeyer (1965) in their text but not in their summary table. An M.S. thesis by Stottlemeyer (1964) was not noted. After termination of the data acquisition portion of this project, we located the original data of Stross and Stottlemeyer (1965) for the period 1963-1964 and unpublished data of Stross for 1960-1961. These data should be added to the data base. Other omissions can be found in Table C-4, particularly the unpublished data of Allison (1964).

Mihursky and Boynton (1978) noted several historical changes in water quality in the Patuxent estuary. They observed that over the period of record there have been increases in annual maximum concentrations of the major nutrients, increases in concentrations of plant pigments and rates of primary production, decreases in the transparency of the water and decreases in the concentrations of dissolved oxygen in bottom waters in some parts of the estuary. On the following pages we will attempt to document the observed changes.

Flemer and Heinle (1974) noted increased maximum concentrations of nitrate in the spring and phosphorus in the summer at Lower Marlboro and Trueman Point based on the work of Herman et al. (1968) (M022001) and that of Flemer, et al. (1970) (M022003). Mihursky and Boynton (1978) added

Table C-4. Water quality studies of the Patuxent River.

Area Studied	Sampling Interval	Study Duration	Measurements Taken[1]	Reference
Solomons-Lower Marlboro	Monthly	1936-37	NO_2^-, NO_3^-	Nash, 1947
	Monthly	1936-39	S, T, SO_4, DO	Nash, 1947
		1944-46	pH	Nash, 1947
	Seasonal	1936-37, 1944	Plk	Nash, 1947
Chesapeake Biol. Lab.	Daily	1937-1946	T, S, TH	Nash, 1947
Solomons-Lower Marlboro	Monthly	1937-39	T, S, SD, DO	Nash, 1947
Chesapeake Bay-Lower Marlboro	Single measurement	15 Aug. 1939	DIP, Chlo	Newcombe and Brust, 1940
Chesapeake Biol. Lab.	Daily	June-Sep. 1939	DIP, SD	Newcombe and Brust, 1940
	Hourly	16-17 June 1939	DIP, Chlo	Newcombe and Brust, 1940
		5-6 Sep. 1939	DIP, Chlo	Newcombe and Brust, 1940
		14-15 Sep. 1939	DIP, Chlo	Newcombe and Brust, 1940
Solomons	Daily	1938-1959	T, S	Beaven, 1960
Solomons	Daily	1944-1974	T, S	Ritchie & Genys, 1975
Western Branch-Rocky Gorge	Single observations	Summer 1961 & 1966	T, DO, BOD	FWPCA, 1967
	-	July-Sep. 1965	Coli	FWCPA, 1967
	Single observations	Summer 1965 & 1966	BOD, DO, T	FWCPA, 1967
Rt. 50-Md. Rt. 198	Monthly	Summers 1964-1966	T, pH, Co, BOD, DO, Turb, Se, DS, Cl, Coli, E. Coli	Allison, 1967b
Rt. 50-Md. Rt. 198	Monthly	Jan. 1961-Feb. 1963	Same as above.	Allison, 1967a
Broomes Island-Lower Marlboro	Quarterly	May 1962-Aug. 1964	T, DO, BOD, Se, DS, Turb, Co, Cl, pH, NO_2^-, NO_3^-, NH_3, ON, DIP, TP, S, Coli	Allison, 1964

EPA-287 (Cin.)
(4-76)

Table C-4. Continued (Mihursky and Boynton, 1978)

Area Studied	Sampling Interval	Study Duration	Measurements Taken[1]	Reference
Lyons Creek-Savage	Monthly	Jan. 1963-Dec. 1966	Se, DS, Turb, DO, BOD, Co, T, pH, Ch, Coli	Allison, 1967b
Broomes Island-Lower Marlboro	Monthly	July 1963-Feb. 1965	T, S, Turb, NO_3^-, DIP, $VSiO_2$, Chl	Herman et al., 1968
Queentree, Benedict, Chalk Point, Eagle Harbor, Lower Marlboro	Daily	1963-65	T (surface)	Cory & Nauman, 1967
Benedict	Daily	1963-65	T, S, DO, Turb, TH, W	Cory & Nauman, 1967
Queentree, Benedict, Chalk Point, Eagle Harbor, Lower Marlboro	Daily	1966-67	T (surface)	Cory & Nauman, 1967
Benedict	Daily	1966-67	T, S, DO, Turb, TH, W	Cory & Nauman, 1968
Hills Bridge-Md. Rt. 198	Single observations	March 1967 July 1967 Sept. 1967	TP, TKN, NO_2^-, NO_3^-	FWPCA, 1969
Hills Bridge-U.S. Rt. 1, Savage	Seasonal	Mar., July, Sept., Oct. 1967	T, TP, DIP, TKN, NO_2^-, NO_3^-, Turb, DO, BOD	EPA, 1967
Md. Rt. 214-Md. Rt. 198 & Md. Rt. 424-Simmons Bridge	?	July 7-Aug. 11, 1955, Mar. 20-24, 1967	T, BOD, DO	FWPCA, 1968a
Md. Rt. 214-Md. Rt. 198	?	Mar. 20-24, 1967	T, BOD, DO, TP, TKN, NO_2^-, NO_3^-	FWPCA, 1968a
Little Patuxent	?	Mar. 20-24 1967	T, BOD, DO, TP, TKN, NO_2^-, NO_3^-	FWPCA, 1968a
Md. Rt. 4-Md. Rt. 198	?	July 31-Aug. 2, 1967	T, BOD, DO, TP, TKN NO_2^-, NO_3^-	FWPCA, 1968a

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
DROPPED HEAD-BEGIN SECTIONS HERE
CENTER OF PAGE
TOP OF IMAGE AREA
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

Table C-4. Continued

Area Studied	Sampling Interval	Study Duration	Measurements Taken[1]	Reference
Md. Rt. 4-Md. Rt. 198	?	Sept. 6-8, 1967	As above	FWPCA, 1968a
Little Patuxent	?	Sept. 6-8, 1967	As above	FWPCA, 1968a
Md. Rt. 4-Md. Rt. 198	?	Oct. 23-25, 1967	T, BOD, DO, TP, Coli, E. coli.	FWPCA, 1968a
Little Patuxent	?	Oct. 23-25, 1967	As above	FWPCA, 1968a
Mainly above Md. Rt. 4; some data to Drum Point.	Seasonal to monthly	1967, 1968, 1974, 1975 1976	Most water quality parameters; measurements not complete for all stations.	WRA, Pers. Comm.
Sheridan Point-Rt. 50 Bridge	Seasonal	Apr., May, June Aug., Sep. 1968	S, T, pH, SD, TP, TKN, NO_2^-, NO_3^-, NH_3, Turb, Chl, DO	EPA, 1968
Queen Anne's Bridge-U.S. Rt. 1	Single measurement	July 1968	TP, TKN, NO_2^-, NO_3^-, NH_3, Turb, Chl.	EPA, 1968
Jones Point, Long Point, Sheridan Point	Single observations	1968-1970 Summer	Most water quality parameters.	ANSP, 1970a, b
Broomes Island-Hills Bridge	Monthly	2 years-Aug. 1968-Aug. 1970	T, S, L, SD, DO, Se, Chl, PC, DOC, PN, PCa, TP, DOP, PP, DIP, NH_3, NO_2, NO_3, DON	Flemer et al., 1970
Broomes Island-Hills Bridge	--------------As in Flemer et al. (1970)	-----------------	-----------------	Flemer et al., 1969
Sheridan Point-U.S. Rt. 50 Bridge	Bimonthly	1969	T, SD, Con, S, TP, DIP, TKN, NO_2^-, NO_3, NH_3, Chl, Turb, DO	EPA, 1969
Sheridan Point-Md. Rt. 198 & Little Patuxent	Monthly	1970	T, TP, DIP, TKN, NO_2^-, NO_3, NH_3, DO, BOD, TOC, Chl	EPA, 1970

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Table C-4. Continued

Area Studied	Sampling Interval	Study Duration	Measurements Taken[1]	Reference
Drum Point-Jug Bay	Hourly	One diel period 18 Oct. 1972	T, S, DO, Z, SD, Chl, PN, PCa, NH_3, NO_2^-, NO_3^-, TKN, DIP, DOP, DOC, PC, Se	Ulanowicz & Flemer, 1977; Ulanowicz et al., 1978
Entire River	Apr., June, July, Oct.	1973	T, S, Cond, DO, BOD, TOC, TKN, NH_3, NO_2^-, NO_3^-, DIP, TP, Chl	Maryland Environmental Service, 1974
Patuxent Basin	?	Summer 1973	?	Pfeiffer, 1974
Lower Marlboro	Hourly	July 28-31, 1975 Aug. 20-21 Oct. 14-16	T, S, Con, SD, pH, TP, DP, DIP, TKN, NO_2^-, NO_3^-, NH_3, DO, BOD, TOC, TC, Chl, Phae, Cl, Turb, Coli, F. coli.	Pfeiffer and Lovelace, 1973

---

[1] T, temperature; S, salinity; DO, dissolved osygen; Z, zooplankton; SD, secchi disc; Chl, chlorophyll *a*; PN, particulate nitrogen; PCo, particulate carbohydrate; NH_3, ammonia; NO_2^-, nitrite; NO_3^-, nitrate; TKN, total Kjeldahl nitrogen; DIP, dissolved inorganic phosphorus; F. coli, fecal coliforms; DS, dissolved solids; Co, color; ON, organic nitrogen; Cl, chlorides; Turb, turbidity (Jackson units); Coli, coliform (mpn); TOC, total organic carbon; TC, total carbon (organic & inorganic); Phae, phaeopigments; Plk, plankton; TH, tidal height; Con, conductivity; BOD, biological oxygen demand; DON, dissolved organic nitrogen; Chlo, chlorinity; SO_4, silicate; pH, inorganic phosphorus; DOP, dissolved organic phosphorus; DOC, dissolved organic carbon; PC, particulate carbon; Se, seston; L, light transmission (subphotometer); TP, total phosphorus; PP, particulate phosphorus.

comparisons with the earlier data (M022005) and a few observations made in 1972 and 1976. Figures C-17 and C-18 show time related changes in nitrate and phosphate (two of the more reliable parameters from the historical data set) for a group of stations within the sediment trap portion of the estuary and a group of stations from the middle and lower estuary where two-layered circulation typically occurs (Owens, 1969). Data taken by CBL in 1978, 1979, and 1980 as well as some data taken by the State (not included in our data base, Appendix B), have been added.

It appears that annual maxima of nitrate concentrations have increased historically (Figs. C-17). Winter maxima of nitrate concentrations on the average are highest and may be good indicators of nitrogen loading. Maximum winter-spring concentrations are now considerably higher than during the studies of Newcombe, Nash and co-workers in the late 1930's (M022005) or those of Herman, et al. (1968) (M022001). The annual cycle of nitrogen concentrations in the lower estuary remains qualitatively unchanged, however, with very low values typically occurring from mid-June until October or November (Fig. C-17) (Mihursky and Boynton, 1978; P.A.N.S., unpublished data). The synoptic study of Ulanowicz and Flemer (1978) (M020001) indicated a very close coupling between primary production and rates of disappearance of nitrogen from solution during October.

Maximum concentrations of phosphorus have clearly increased upstream of Benedict Bridge (Fig. C-18). Downstream of the bridge, where phosphorus concentrations are considerably lower, presumably as a result of dilution of phosphate-rich freshwater by relatively phosphate-poor salt water, there appears to have been a modest increase in concentration maxima also (Fig. C-18). On the average, summer phosphate concentrations, below Benedict Bridge, have increased rather dramatically. Presumably, increased phosphate loadings from upriver and increased rates of phosphate release by the estuarine benthos both contribute to this effect, but further resolution of this will await further research and study. Clearly, phosphorus flux information is needed.

On the basis of the 1968 to present data set, it appears unlikely that phosphorus limitation is a factor upstream or downstream of the bridge through most of the spring and summer. Such limitation may have been present prior to that period, however, when phosphorus loadings were smaller. Conclusions about the possibility of nitrogen limitation occurring are difficult to reach on the basis of the nitrate concentration data alone, for other forms of inorganic nitrogen such as ammonia (historical data for which are scarce and have poor reliability), need also be considered. However, nitrogen limitation below Benedict Bridge seems quite possible considering the data presented in Figures 17 and 18. In addition, light limitation should be considered a strong possibility upstream.

An interesting phenomenon noted by Webb (unpublished) during our study was that a late summer-early fall and, to a lesser extent, an early spring NO_2^--N concentration maximum occurs in many localities in the Bay. Webb and D'Elia (1980) have reported high concentrations of NO_2^--N in the water column exceeding 5 uM (0.07 mg/l) for the lower York River. Figure C-19 shows a striking example of this seasonality in unpublished data we acquired from

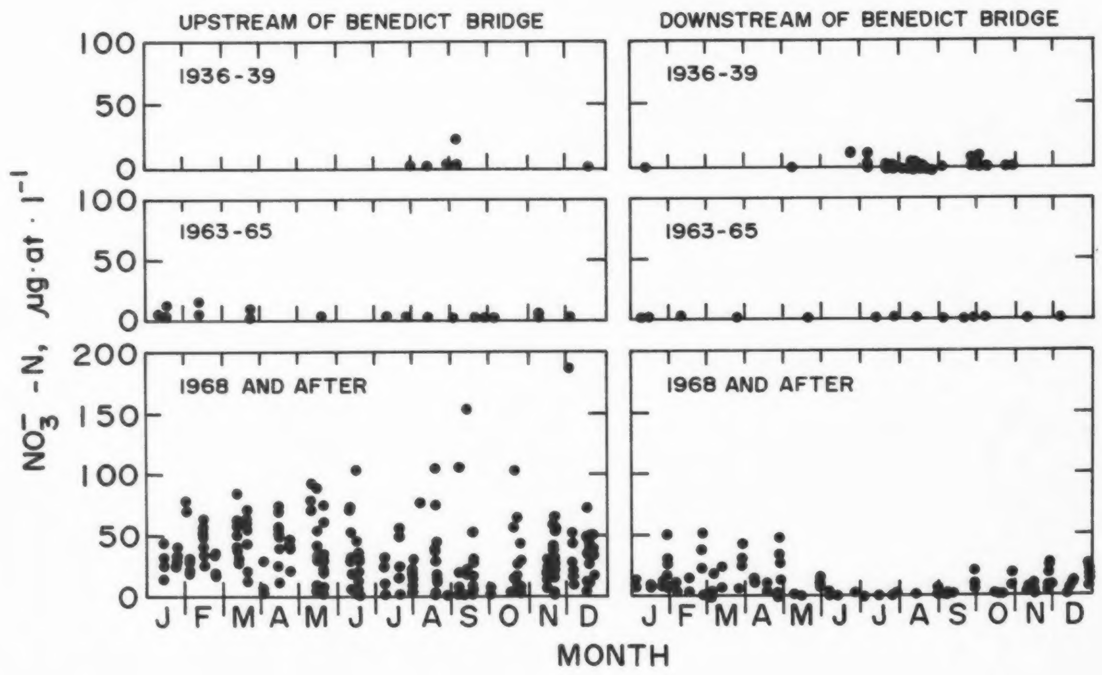


Figure C-17. Concentration of nitrate (ug-at l^{-1}) in surface waters of the Patuxent River upstream from Benedict Bridge and downstream from Benedict Bridge during various time periods.

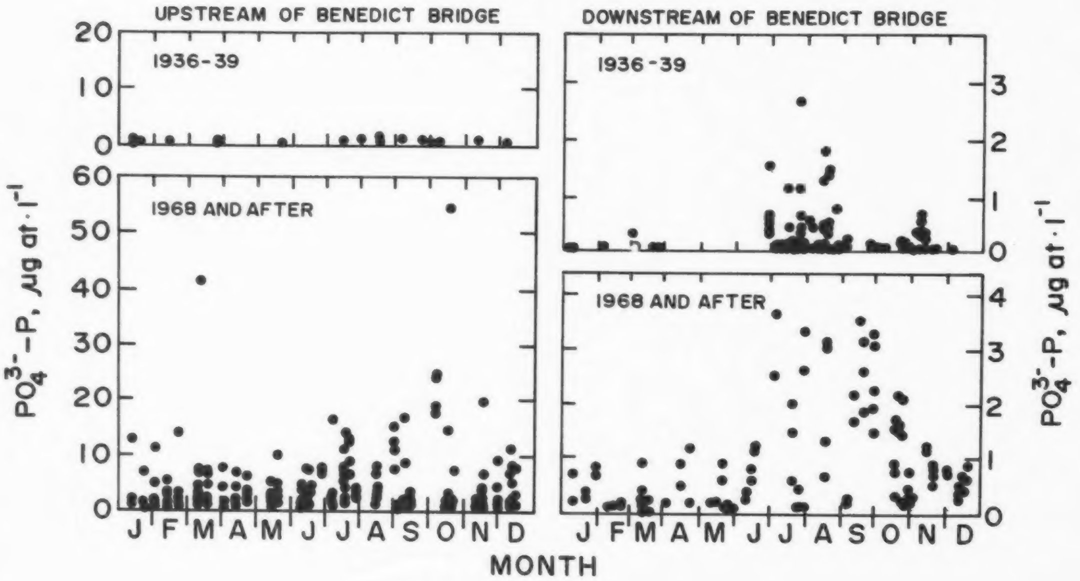


Figure C-18. Concentration of orthophosphate-P in surface waters of the Patuxent River upstream from Benedict Bridge and downstream from Benedict Bridge during various time periods.

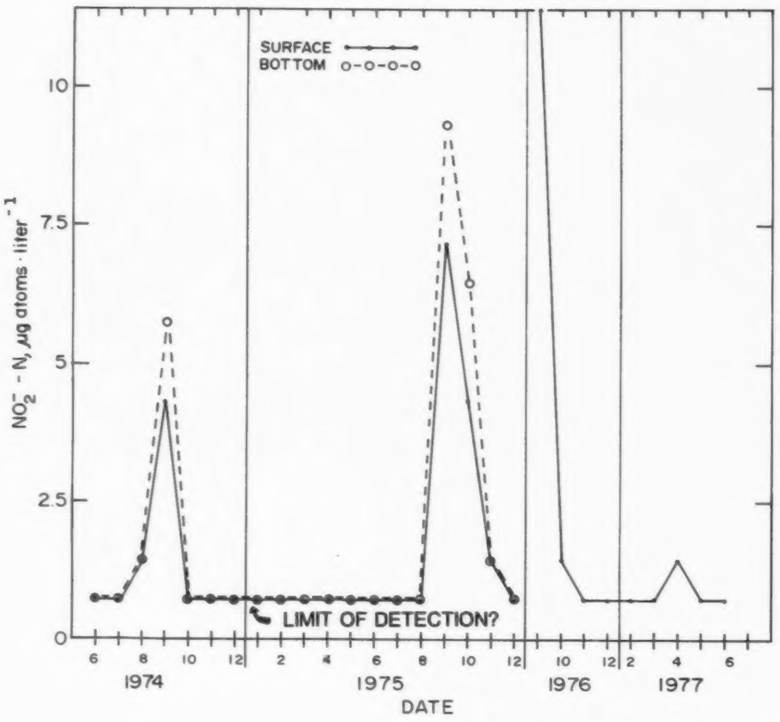


Figure C-19. Concentrations of nitrite-nitrogen in surface and bottom waters at Benedict, Md. 1974-1977 (from data summaries provided by the Philadelphia Academy of Natural Sciences).

P.A.N.S. for the Patuxent River near Benedict, Maryland. Such observations militate against the commonly accepted notion that NO$_2^-$-N is never abundant enough to be worthy of measurement. Morever, Webb (1980) has suggested that in addition to its importance as a seasonal factor in the Bay, NO$_2^-$-N may be an important indicator of historical enrichment trends in the Bay. An ongoing research program in 1980 has again verified a late summer-late fall NO$_2^-$ maximum throughout the Bay, with NO$_2^-$ concentrations reported which exceed 10 uM.

Methods used to measure primary production in the Patuxent estuary vary, but those of Stross and Stottlemeyer (1965) and of Flemer, et al. (1970) were nearly identical. Rates of primary production appear to have increased between 1963-1964 and 1969-1970 in approximate proportion to the increases in concentrations of chlorophyll, described below. There were large year-to-year differences in rates of primary production during both studies.

Maximum concentrations of chlorophyll a have increased considerably in the lower Patuxent estuary (downstream from Benedict) since the first measurements were made by Stross and Stottlemeyer (1965) and by Herman, et al. (1968) (M022001) in 1963-1964. In 1963-1964 maximum concentrations of chlorophyll a were up to 18 ug l^{-1} at Benedict and downstream and up to 40 ug l^{-1} at Lower Marlboro during May, June and July (Fig. C-20). By 1968 concentrations of chlorophyll a of up to 60 ug l^{-1} were observed at Benedict and Lower Marlboro. During 1970 and 1973, concentrations of chlorophyll a up to 80 to 100 ug l^{-1} were observed, and few observations were as low as the 1963-1964 data. During 1977 and 1978 many of the observations in the lower estuary were within the range reported for 1963-1964, but many were higher. Extreme values of over 100 ug l^{-1} were observed in 1978.

Similar trends occurred during the months of August, September and October except that concentrations at Lower Marlboro were somewhat higher during those months than during May-July in 1963-1964, and did not increase in later years (Fig. C-21). The increases in chlorophyll a from 1968 and later at stations in the lower estuary were not as dramatic as during the months of May-July, for maxima greater than 60 ug l^{-1} were not observed.

Chlorophyll a concentrations measured in the Patuxent during the winter months after 1970 (by P.A.N.S.) have not been made available to us, but the data of Flemer, et al. (1970 (M022003) indicate an increase over the concentrations found in 1963-1964 (Fig. C-22).

Inasmuch as methods for measuring chlorophyll were not well developed until the 1950's, we cannot determine with certainty if standing stocks of phytoplankton increased in the Patuxent estuary between the studies in the 1930's and those of Herman, et al. (1968) (M022001). It seems likely, however, that increased algal stocks would result in increased turbidity, particularly in the portion of the estuary downstream from the sediment trap region (the sediment trap region varies in salinity, but is generally upstream from Benedict). Turbidity, measured as Secchi depth, was recorded in the earliest studies. The same technique continues in use today, although other measures of turbidity, convertible to Secchi depth, are also used. Examination of Secchi depth, as a function of salinity and month, revealed

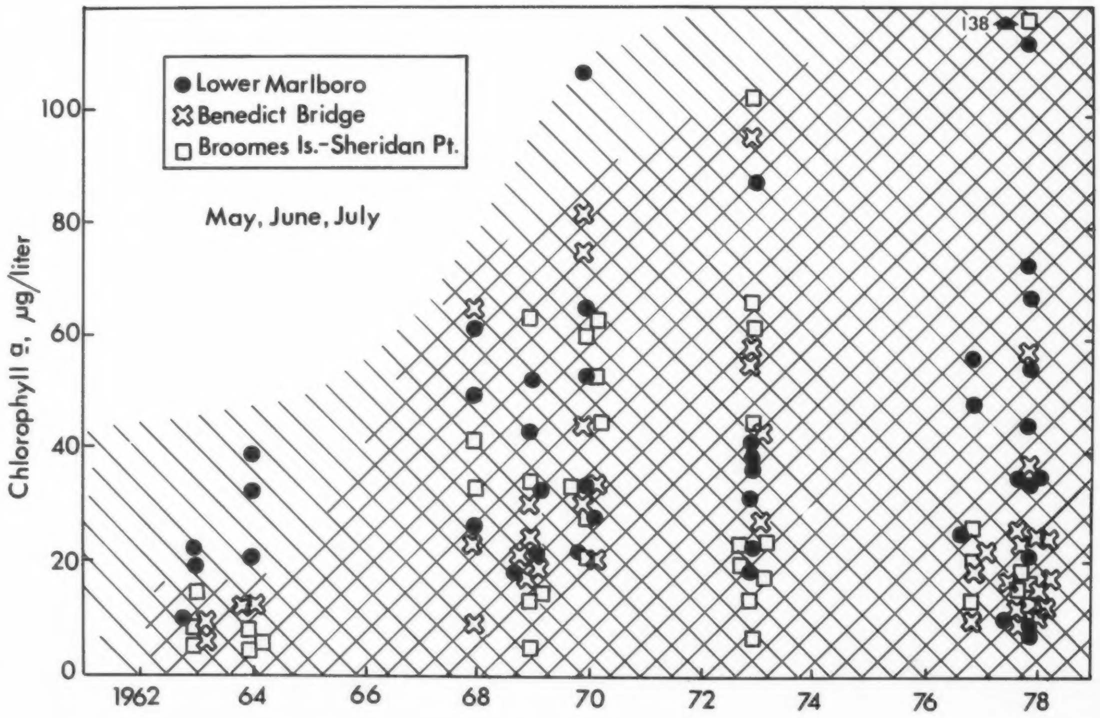


Figure C-20. Concentrations of chlorophyll a in surface waters in three portions of the Patuxent River, May-July, 1963-1978.

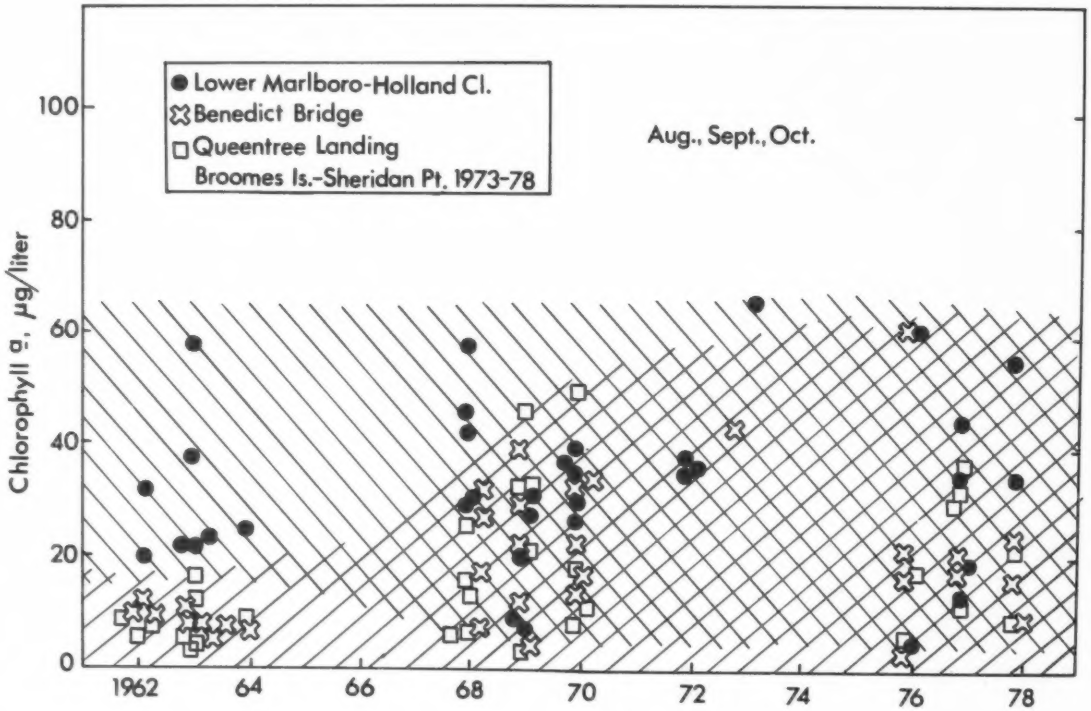


Figure C-21. Concentrations of chlorophyll a in surface waters in three portions of the Patuxent River, August-October, 1962-1978.

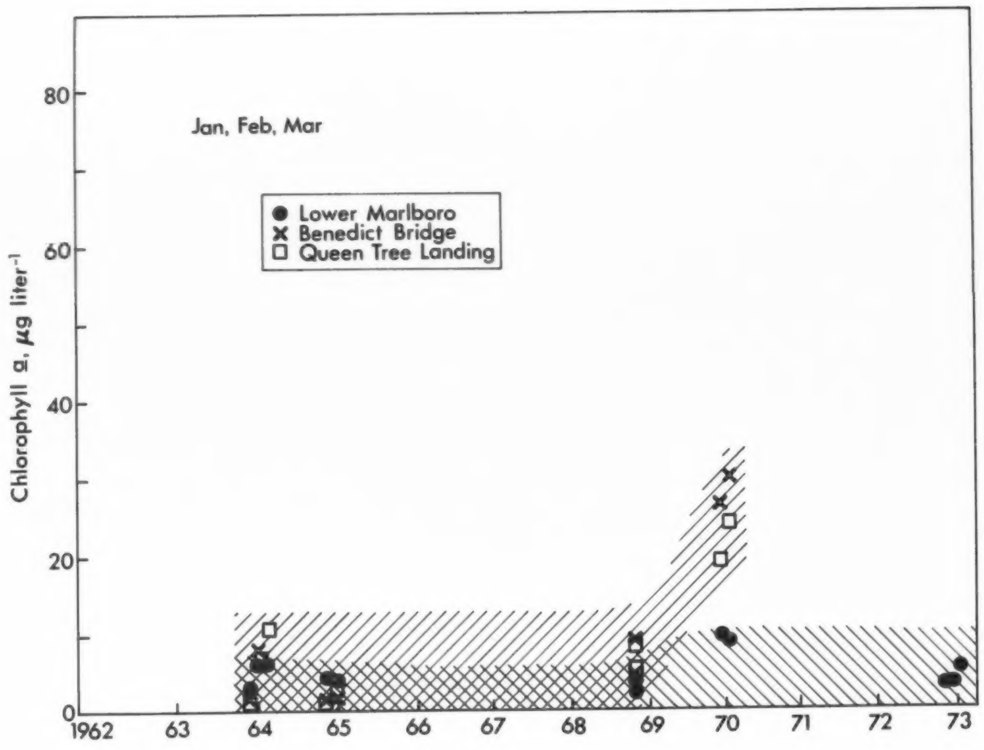


Figure C-22. Concentrations of chlorophyll a in three portions of the Patuxent River estuary, January-March, 1963-1972.

that the most notable decreases occurred in the months of July, August and September (Fig. C-23), from 1969 onward, a feature shared by the central Bay (Fig. C-4). Surface salinity was chosen as the abcissa (x-axis) in Figure C-23 rather than location in the estuary because of the effect that varying flows have on the position of the sediment trap. High concentrations of inorganic sediment occur in parts of the Patuxent characterized by salinities less than 8 ^{o}/oo in July and less than 10 to 12 ^{o}/oo in August and September (Fig. C-23). Secchi depths in excess of 1.5 m were common in the early studies at higher salinities. Transparencies of the water in the lower estuary during 1963 were similar to those observed during 1936-1940. The 1963 values were calculated from optical densities (O.D.) in original data of Stross and Stottlemeyer (1965) (located too late for inclusion in our data base). Stross and Stottlemeyer found O.D. from $\log I_z - \log I_{z+1}$ (Sverdrup, Johnson and Flemming, 1942). We calculated extinction coefficients (K) as 2.3 O.D. (Sverdrup, et al., 1942) and then used the relationship Secchi depth equals 1.43K established for Chesapeake Bay by Keefe and Flemer (1976). Stross and Stottlemeyer observed even greater Secchi depths during July of 1964 than during 1963 in the lower estuary; five observations in excess of 3m and two over 5m, but unfortunately did not measure salinity on that date.

We feel that the decreased Secchi depths in the lower estuary during July-September in later years reflect increased algal stocks. There is less certainty concerning the much smaller decreases in Secchi depth in the sediment-trap part of the estuary (salinities < 8 ^{o}/oo) shown in Figure C-23 and reported also by Mihursky and Boynton (1978) in their Figure IV-3 reproduced here as Figure C-24, as turbidity in that part of the estuary is greatly affected by wind (Cory and Nauman, 1970). The seasonal patterns of salinity and temperature in the Patuxent during the early studies (MO22005) were similar to those observed by Flemer, et al. (1970) (MO22003) (Fig. C-24), so Secchi was probably not greatly decreased by higher flows during the later studies. In addition, we often noted comments on the original field notes such as "Bay too rough, went to river instead," suggesting that many of the early trips on the Patuxent, especially during 1936 were made on windy days. One might, therefore, expect higher turbidity than was characteristic of the period. The increase in turbidity between 1936-1940 and 1969-1970 in the sediment trap area thus probably represents a real change in the character of the estuary. We do not know if this represents increased algal stocks or increased amounts of detritus and sediment, or both.

One of the most common effects of excessive enrichment is increased community metabolism indicated by higher concentrations of dissolved oxygen (D.O.) during daytime and lower concentrations of D.O. at night. Cory (1974) noted evidence for such changes in the Patuxent at Benedict during the period 1963 thorugh 1969. He observed both greater extremes in concentration of D.O. and a reduced ratio of production to respiration, from 0.84 in 1964 to 0.60 in 1969, suggesting increased heterotrophy at the study location. Cory installed his automatic sampling apparatus again in 1977. Although the results have not been published, they have been made available for our use through the U.S. Geological Survey (U.S.G.S.). Figure C-25 shows weekly maximum and minimum concentrations of D.O. during May through August at 1-m depth at Benedict Bridge. Maximum concentrations have clearly increased and

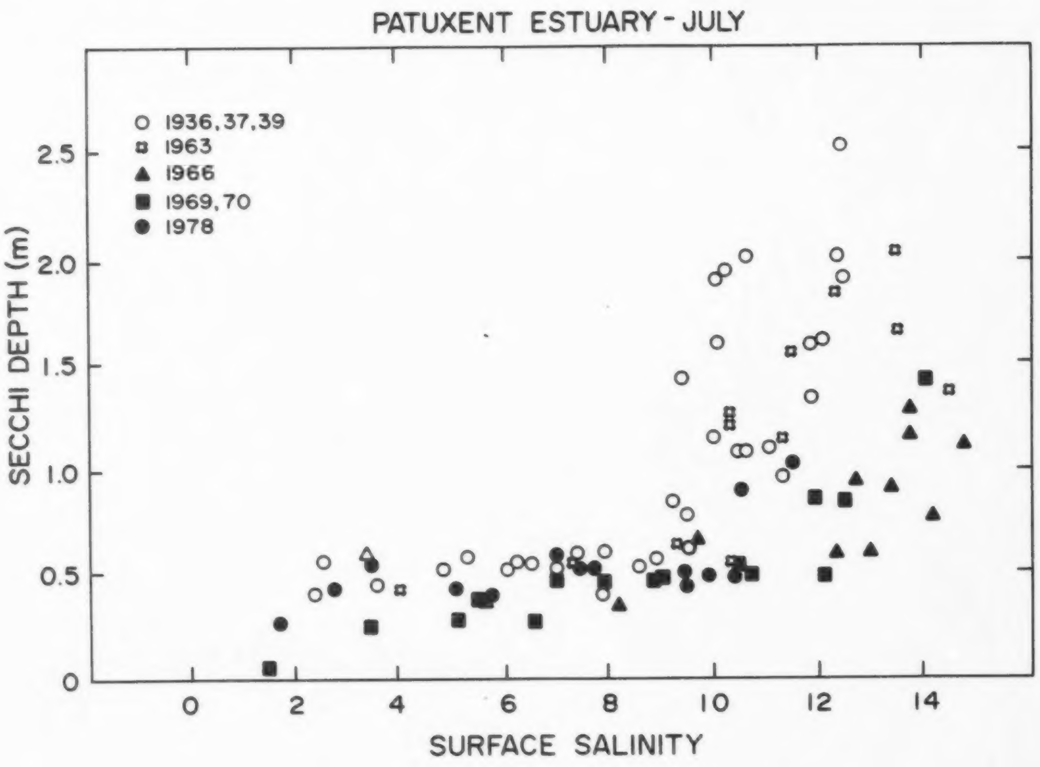


Figure C-23. Secchi depth during July in the Patuxent estuary plotted against salinity.

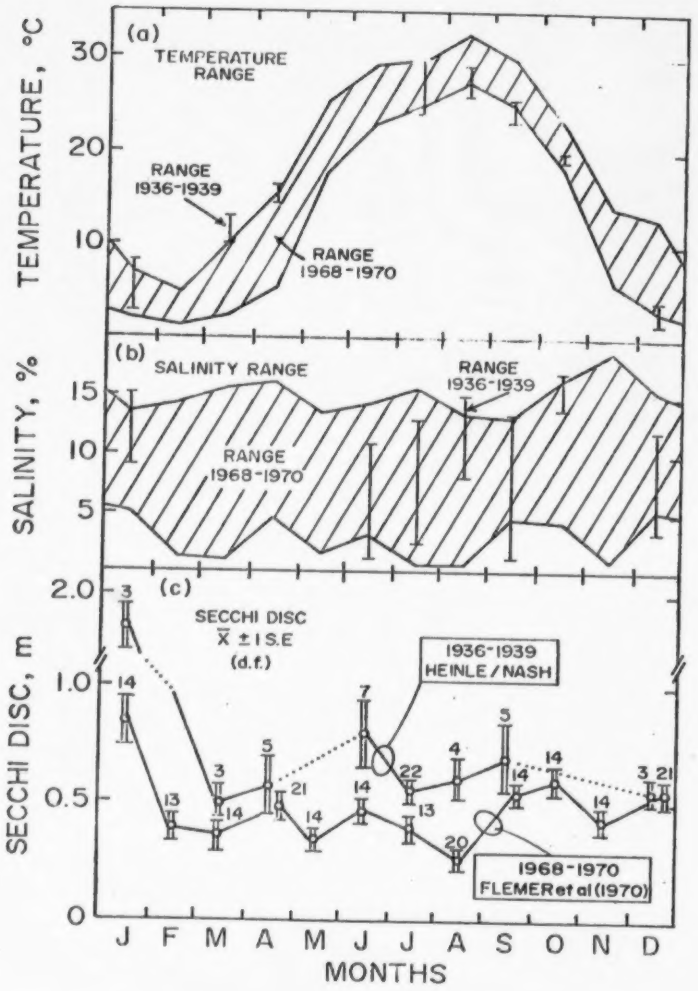


Figure C-24. Ranges of temperature, salinity, and Secchi depth in the "turbidity maximum" area of the Patuxent estuary (from Mihursky and Boynton, unpbulished).

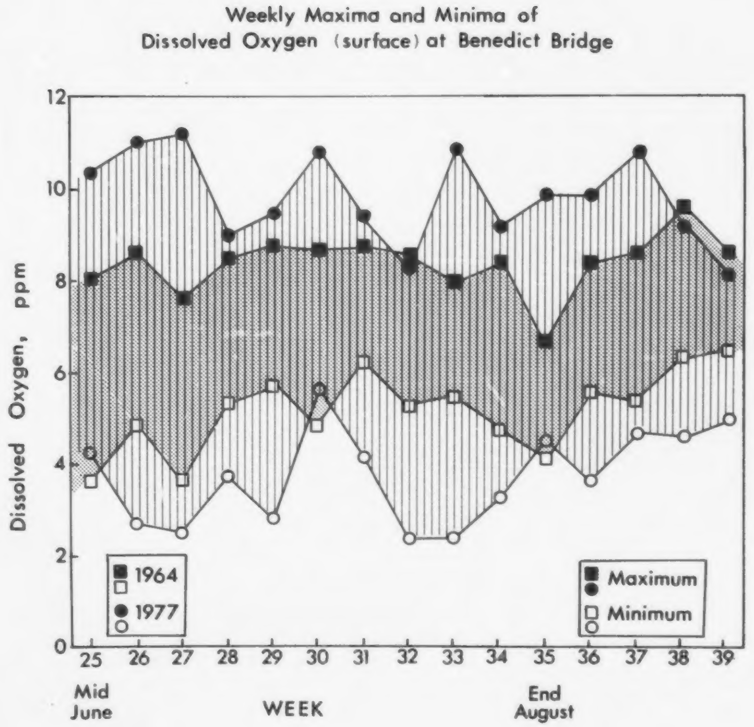


Figure C-25. Weekly maximum and minimum concentrations of dissolved oxygen at Benedict Bridge over the Patuxent River estuary during 1964 and 1977 (from data of R. L. Cory, U.S. Geological Survey).

minimum concentrations have clearly decreased at that location. A similar change, but of lesser magnitude has occurred in the weekly mean of daily maximum and minimum concentrations. Concentrations ranged between 33 and 147 percent of saturation in 1977, nearly identical to the range observed in 1969 by Cory (1974).

In a stratified body of water, such as an estuary, increased productivity in surface waters can cause decreased concentrations of oxygen in deeper waters (e.g., Curl, et al., 1978; Glendening and Curl, 1978; Webb and D'Elia, 1980). A phenomenon like this is known to occur naturally in the central part of Chesapeake Bay (Newcombe and Horne, 1938). Measurements of surface and bottom concentrations of D.O. in the Patuxent estuary during 1936-1939 (M022005) provide a basis for comparison of more recent data. Nash (1947), in discussing the annual cycle of dissolved oxygen at a station near the mouth of the River, stated that concentrations in bottom waters at upriver stations were sometimes 40 percent of saturation. A survey of the data base (M022005) revealed that concentrations of D.O. were only occasionally lower in bottom waters than in surface waters during July and August at locations upstream from St. Leonard's Creek during 1936-1939. Low concentrations of dissolved oxygen were commonly observed downstream from the mouth of St. Leonard's Creek in the early data. Figure C-26 shows all measurements from the mouth of the Patuxent (Drum Point) upward to Lower Marlboro taken during July of 1936-1939. Measurements made during 1977-1979 by the State of Maryland, W.R.A., and by the University of Maryland, CBL, mainly during studies funded by the State of Maryland, Power Plant Siting Program (PPSP), are shown for comparison. It can be seen in Figure C-26 that the recent measurements tend to be somewhat lower in portions of the estuary where the ranges of the two periods overlap. In the segment of the estuary from Benedict Bridge to Jack Bay (Stations 17 to 13 of Nash, 1947) the concentrations observed during July of 1977-1979 were all lower than in the early period.

Nash (1947) observed that the differences between surface and bottom concentrations of D.O. were sometimes greater when vertical stratification was stronger. Some of the high (near saturation at 5-6 ppm) concentrations in bottom waters in the early data (Fig. C-26) were observed during periods of apparent vertical mixing as salinity differences were near zero. The very high concentrations in the lower estuary appear, from examination of the original laboratory notes, to be valid observations of super-saturation in deep waters, and were often higher than surface concentrations at the same locations. Stross and Stottlemeyer (1965) calculated that the depth of the euphotic zone was often deeper than 5 m in the lower estuary; about the depth of the halocline, which from vertical profiles of salinity from both periods usually lies at about 5 to 6 m in the lower Patuxent above Point Patience and somewhat deeper below Point Patience. Their observations of Secchi depths of 3 to 5 m in July suggest that the euphotic zone could be 9 to 15 m deep at times. It, thus, appears likely that photosynthesis occurred below the halocline during periods of greater clarity of the water, i.e., prior to 1966 (Figs. C-24 and C-25), perhaps causing the observed super-saturation below the halodine.

During the months of September through May, concentrations of D.O. in

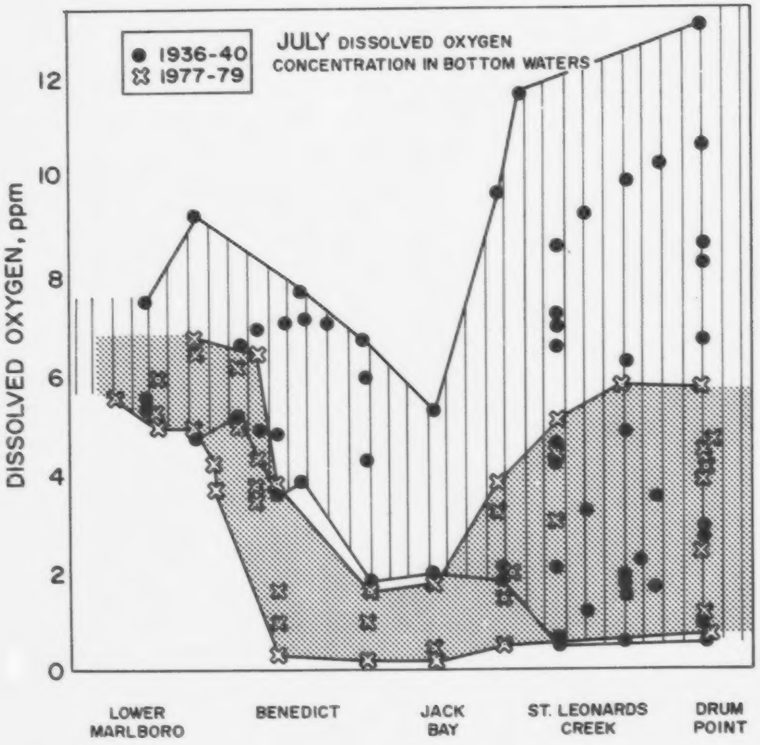


Figure C-26. Concentrations of dissolved oxygen in bottom waters of the Patuxent River estuary during the month of July, 1936-1940 and 1977-1979.

bottom waters in the Patuxent estuary were not markedly different from surface concentrations, and showed no trends with time. Low concentrations of D.O. (less than 1 ppm) were observed in bottom waters from Benedict to Broomes Island in June of 1978 (no data for 1977 or 1979) and August of 1977 and 1978 (Fig. C-27). The only observation of a concentration less than 1 ppm in the early data is a single value of 0.78 ppm in August, 1939 at Sheridan Point (Fig. C-27). Allison (1967) observed one value of 1.6 ppm at the bottom at Benedict Bridge in August of 1961. Surface concentrations of D.O. in point samples from the Patuxent do not clearly show the trend apparent in the data of Cory (Fig. C-25).

The reduced concentrations of D.O. in bottom waters between Benedict and Broomes Island appear to be caused by respiration and decomposition of organic matter produced within the Patuxent estuary rather than by intrusion of Bay waters naturally low in D.O. Although low concentrations of D.O. are often observed below Broomes Island, on occasions when concentrations are low above Broomes Island, they are frequently higher downstream near the mouth of St. Leonard's Creek. This can be seen in the data from 1977-1979 in Figure C-26. Detailed observations of the vertical distribution of D.O., salinity and *in vivo* fluorescence in the lower estuary during the summer of 1979 by Mr. Stephen Domotor of the Chesapeake Biological Laboratory clearly show diminishing concentrations of D.O. as one proceeds upstream from the confluence with Chesapeake Bay during periods of vertical stratification.

As nutrient loading to the Patuxent increased through the 1960's (Chapter B), maximum concentrations of nutrients in the estuary also increased (Figs. C-17 and C-18). Concentrations of nitrogen still decrease to near the limits of detection during the summer and fall and thus may limit phytoplankton growth, but concentrations of phosphorus now remain somewhat higher all year. Webb and D'Elia (1980) have shown how diminished concentrations of D.O. in bottom waters is correlated with increased phosphorus concentration, presumably from accelerated rates of release of phosphorus from the sediments, a phenomenon that probably now occurs in the lower Patuxent estuary. Increased nutrients have led to increased concentrations of chlorophyll *a* (Figs. C-20, C-21, C-22), primary production and increased community metabolism (Fig. C-25), perhaps with a decrease in production to respiration ratio (Cory, 1974). Increased surface production coupled with a diminished euphotic zone in the lower estuary which is often vertically stratified have led to greatly reduced concentrations of D.O. in that portion of the Patuxent. Low concentrations of D.O. have caused mortalities of oysters at depths greater than 5 m between Benedict and Broomes Island (Krantz, pers. comm.). From about 1976 onward, eel fishermen have observed mortalities in their traps in the lower Patuxent estuary. While concentrations of D.O. of less than 2 ppm were sometimes observed in the early data, protracted periods of that condition, such as observed in 1977 and 1978 apparently did not occur. Finally, the minimum concentrations observed in recent years at the surface (approaching 2 ppm; Fig. C-25) are reaching levels that can be expected to cause mortalities of fish.

POTOMAC RIVER

The Potomac River estuary has been studied with varying intensity since

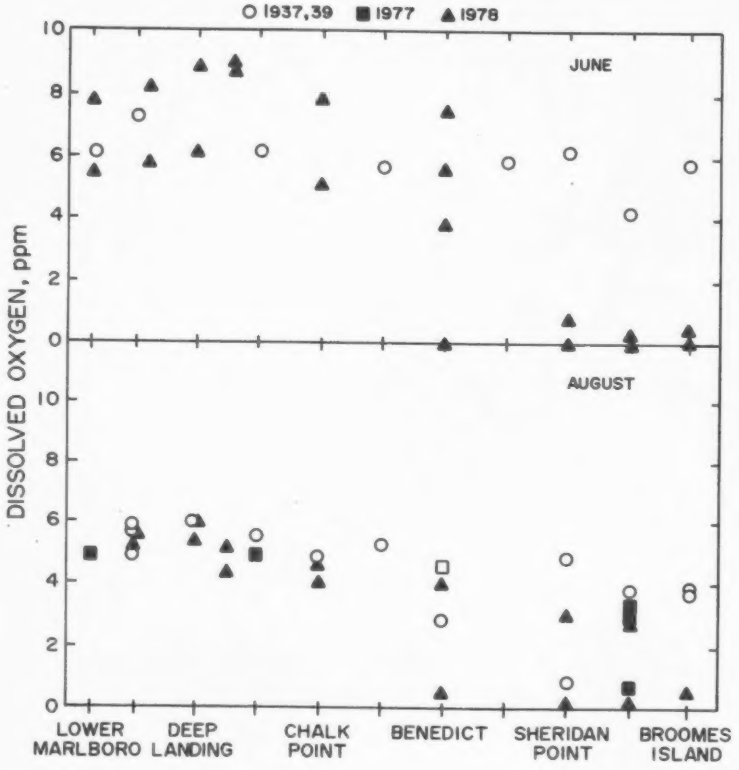


Figure C-27. Concentrations of dissolved oxygen in bottom waters of the Patuxent River estuary during June and August 1937-1939 and during 1978.

1913. Wolman (1971) reviewed the history of the effects of a growing population on continuing efforts toward improvement of water quality in the Potomac. Early efforts were devoted to the reduction of B.O.D. by providing first primary treatment in 1938 (Wolman, 1971) and later adding secondary treatment in the late 1960's (see Fig. B-1).

As the most apparent problems in the Potomac were in the upper reaches near Washington, D.C., most of the scientific and monitoring efforts have been concentrated on the upper watershed and the tidal-fresh portion of the estuary. Cumming, Purdy and Ritter (1916) apparently sampled nutrients and dissolved oxygen over the oyster bars in the lower estuary during 1913, but our efforts to locate their unreported data were unsuccessful. The first studies of water quality that encompassed the length of the estuary were those of C.B.I. during 1965-1966, reported by Carpenter, Pritchard and Whaley (1969). By the time of those studies, chlorophyll *a* concentrations of 80 to 100 ug l^{-1} were common in the portion of the estuary up to 20 miles or more downstream from Washington, D.C. As reported by Wolman (1971) problems with reduced concentrations of oxygen were common, and other workers had noted the additional demand for oxygen caused by excessive algal blooms including blue-green algae (Jaworski, Lear and Villa, 1971; 1972; Jaworski, Clark and Feigner, 1971). Comparison of the 1965-1966 data with the results of intensive surveys during 1969-1971 (U.S.E.P.A., 1970a,b,c) (M022038, M022042, M022043) by Jaworski, et al. (1972) showed no trends for that period, concentrations of chlorophyll *a* exhibiting the same seasonal patterns in both surveys, and concentrations of both major nutrients being relatively high. Reviews of data from more recent water quality surveys by E.P.A. (Pheiffer, 1975; Villa, Clark, Roesch and Smith, 1977; Clark and Roesch, 1978) which were conducted after the implementation of phosphorus removal at the Blue Plains sewage treatment plant show reduced concentrations of phosphorus in the upper Potomac. Concentrations of nitrogen were similar to those found in previous surveys and concentrations of chlorophyll *a* were as high or higher than previously observed.

The floating mats of blue-green algae that were prominent during the 1960's were not observed in the most recent studies, but blue-green algae still dominated the blooms. *Anacystis cyanes*, the blue-green algae dominant during the 1960's was not abundant in the work reported by Pheiffer (1975), Villa, et al. (1977), and Clark and Roesch (1978), and while concentrations of chlorophyll *a* were not reduced, slightly higher concentrations of dissolved oxygen were noted in the most recent studies. It should be noted that in addition to the reduction in phosphorus loadings (Pheiffer, 1975) the 1970's have been relatively wetter than average years (Table A-1) reflected in reduced salinities at mid-Bay (Fig. A-4). It is not yet clear what the effects of flow versus loadings from Blue Plains are on conditions in the upper Potomac. In spite of the effort expended on the upper Potomac estuary to date, there is as yet no clear consensus that improvements will result from the removal of one or the other of the major nutrients. As indicated by Villa, et al. (1977) and Clark and Roesch (1978) the general conclusions reached by Jaworski, Clark and Feigner (1971) are still valid. Control of one or both nutrients will be required to effect improvement in the upper Potomac. If nitrogen removal is necessary, the cost may be high. As continuing efforts are barely maintaining status-quo with regard to B.O.D.

(Anon., 1969a) it may be necessary to look to other tributaries such as the York or Rappahannock, or the upper Bay itself, for clues concerning necessary improvements in water quality.

The lower Potomac (up to about river mile 43, on some occasions) was included in the nutrient, turbidity, D.O., temperature, salinity, and chlorophyll sampling conducted by C.B.I. in 1949-1951 (Hires, Stroup and Seitz, 1963; Stroup and Wood, 1966). Table C-5 shows the concentrations of PO_4^{3-}-P at the surface and chlorophyll a at the surface and bottom observed during 1949-1951. The sampling dates are arranged out of chronological sequence to provide an indication of an annual cycle. Table C-6 shows comparable data from the same stations during the 1965-1966 sampling (Whaley, Carpeneter and Baker, 1966) that was reported by Carpenter, et al. (1969). Concentrations of PO_4^{3-}-P were higher during January to May in the later studies. They were about the same in July and August of both studies and lower at some stations and higher at others during October to November in the later data.

The concentrations of chlorophyll a in the lower Potomac were generally higher in 1965-1966 than during 1949-1951 during all months that were sampled except March-April (Tables C-5 and C-6). In May of 1950 the concentrations of chlorophyll a were higher in bottom waters than at the surface (Table C-5), an intriguing observation in light of the deep-water migrations of dinoflagellates observed in the Bay more recently (Tyler and Seliger, 1978). The same phenomenon occurred on one cruise during May, 1965-1966 but was obscured by the grouping of the data we used (Table C-6). Dinoflagellate "blooms" via the transport phenomenon described by Tyler and Seliger (1978) may thus have occurred in earlier years, although this evidence is weak. The most notable increases in concentrations of chlorophyll a occurred during July. In 1949-1951 concentrations were 3 to 5 ug l^{-1} in surface waters compared to 9 to 13.8 ug l^{-1} during July of 1965.

The slightly higher concentrations of phosphorus and considerably higher concentrations of chlorophyll a during the summer in the lower Potomac estuary suggest early effects of enrichment. The changes in the lower estuary could become more pronounced as greater areas in the upper estuary become light-limited through self shading of dense algal blooms. Under those conditions in other tributaries such as the Patuxent, nutrients appear to pass through the sediment trap (turbid) portion of the estuary and are increasingly being expressed as higher algal standing stocks in the lower estuary. The Potomac is a larger system with greater dilution in the lower reaches by Bay waters, but also stronger vertical stratificaiton. Organic production in the Potomac is thus likely to be retained within the estuary.

While the prognosis for improvement of the upper Potomac estuary through conventional or even advanced waste treatment is poor, removal of nutrients might prevent or delay degradation of the lower estuary.

JAMES RIVER

Aside from the observations of Cumming (1916) in the Hampton Roads-Norfolk area on organic loading and sanitary conditions, and a later

Table C-5. Ranges of concentration at the surface of orthophosphate-P and at surface and bottom chlorophyll a in the lower Potomac estuary during 1949-1951. A dash (-) indicates no data, a single value indicates that only one observation was made.

Dates	Sequence in table	PO_4^{-3}-P (ug-at l^{-1})	Chlorophyll a (ug l^{-1}) Surface	Chlorophyll a (ug l^{-1}) Bottom	Distance upstream (River miles)
18 Aug.-6 Sept., 1949	7	0.2-0.7	-	-	43
25 Mar.-25 Apr., 1950	2	$0.1-0.1^+$	10-21	$12-27^+$	43
20-25 May, 1950	4	0.0-0.1	3-6	$9-24^+$	18
14-19 July, 1950	6	$0.2-0.2^+$	3-5	1-2	33
14 Oct.-2 Nov., 1950	8	$0.3-0.3^+$	$1-9^+$	1-7	33
10-23 Jan., 1951	1	0.0-0.1	1-2	1-2	33
7-19 Apr., 1951	3	- -	13	11	3
21-31 May, 1951	5	0.17	8.2	8.3	18

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD. BEGIN SECTIONS HERE

Table C-6. Ranges of concentrations at the surface of orthophosphate-P (ug-at l^{-1}) and at surface and bottom of chlorophyll a in the lower Potomac during 1965-1966. Only stations within the areas samples in 1949-1951 were used.

	PO_4^{-3}-P	Chlorophyll a Surface	Chlorophyll a Bottom
Jan.	0.25-0.38	3.2-4.6	3.1-5.0
Mar.- Apr.	0.07-2.60	1.1-20.0	1.1-9.5
May	0.04-0.60	5.8-13.2	4.3-9.8
July	0.17-0.32	9.0-13.8	1.0-1.8
Aug.- Sept.	0.37-1.03	9.0-26.4	2.9-9.6
Oct.- Nov.	0.08-1.20	9.3-24.0	3.6-11.0

similar report, the first useful data on the James River begin in 1950 with the early C.B.I. studies. Until the work of Brehmer and Haltiwanger (1966) (M022018) in 1965-1966, no measurements of water quality were found for the James River upstream from river mile 25 (25 nautical miles above the confluence with the Bay). Unfortunately, river flows were unusually low during the summer months of Brehmer's and Haltiwanger's study (their Appendix E).

By the time Brehmer and Haltiwanger began their study, the upper James appears to have already been greatly affected by enrichment. Chlorophyll a concentrations of 50 to 80 ug l^{-1} were common at their upper three stations in the tidal-fresh portion of the estuary, and 20 to 50 ug l^{-1} were often observed at their middle stations. Those observations can be contrasted with earlier data from the upper Bay or the Patuxent where chlorophyll a concentrations in the low-salinity areas were rarely above 30 to 40 ug l^{-1} and often lower in the summer months.

Concentrations of nitrogen in the upper James often show clear gradients with much higher concentrations upstream during October through January, higher concentrations downstream during March and May, and variable patterns the other months, usually with highest concentrations at about river mile 47, the middle of the tidal fresh portion of the River.

Concentrations of orthophosphate-P show no seasonal or longitudinal patterns in the data of Brehmer and Haltiwanger (1966), being generally less than 1.0 ug-at l^{-1} all year. The pronounced summer minimum observed in the earlier data from the upper Bay (Fig. C-1) was completely absent from the data from the upper James in 1965-1966, suggesting again that changes had already occurred.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin)
(4-70)

In the lower James River (river mile 0 to river mile 25), where salinities are higher, the earliest data (Stroup and Wood, 1966; Brehmer and Haltiwanger, 1966) show a minimum concentration of phosphorus in the spring, generally less than 0.5 ug-at 1^{-1}, and slightly higher concentrations in the fall, similar to the pattern described by Newcombe (1940) for the middle Bay. Data collected in the 1970's (Adams, Walsh, Grosch and Kuo, 1975) show markedly higher concentrations of orthophosphate during December through May. Concentrations were similar during June, July and November in all the studies, and slightly higher during August through October in the 1970's (Fig. C-28).

There have been dramatic increases in $NO_3^- + NO_2^-$ - nitrogen in the lower James estuary (Fig. C-29). At the time of the studies by Brehmer and Haltiwanger (1966) (M022018) the seasonal pattern of nitrogen concentrations in the lower James was similar to that in the lower Bay, except that spring maxima were up to 50 ug-at 1^{-1} in the James (Fig. C-29) compared to about 25 ug-at 1^{-1} in the lower Bay (as recently as 1972; McCarthy, et al., 1977). We plotted ranges of data from the mid-channel "reference stations" of Adams, et al. (1975) for the section of the James estuary. Concentrations in the spring months were similar in the two studies, but concentrations during July through December were much higher in the more recent samples of Adams, et al. (1975). At times, but not always, the highest concentrations of nitrogen in the outfall studies of Adams, et al. (1975) were at their station 10 (on their map) designated station 18 in their computer printout. Those high concentrations undoubtedly were the direct result of the Williamsburg sewage outfall a short distance downstream, but nevertheless represent current ambient conditions in the lower James. Deletion of data from that station would not significantly alter the pattern of concentrations shown in Figure C-29. Recall that low flows during the summer months sampled by Brehmer and Haltiwanger (1966) might have resulted in greatly reduced non-point loading of nitrogen during that period.

In spite of the high ambient levels of both phosphorus and nitrogen in the lower James (Figs. C-28 and C-29), concentrations of chlorophyll a have not apparently increased (Fig. C-30). In fact the pronounced spring bloom which sometimes occurs in the lower Bay (Fig. C-16) appears to be absent in the James in the more recent data (Fig. C-30). Brehmer and Haltiwanger (1966) occasionally observed concentrations in excess of 20 ug 1^{-1} of chlorophyll a during March and April which were not seen by Adams, et al. (1975). Brehmer and Haltiwanger (1966) also recorded a significant bloom, up to 17 to 19 ug 1^{-1} of chlorophyll a, in November and December, similar to the early observations of spring and fall "blooms" by Nash (1947) in the lower Patuxent River during the late 1930's. Adams, et al. (1975) found concentrations generally below 7 ug 1^{-1} during the same period.

In the lower James estuary, the apparently unchanged concentrations of chlorophyll a in the presence of relatively abundant nutrients in recent years can be theoretically explained within the framework of the conceptual model proposed by Webb (1980). It is possible, but has not been demonstrated, that accelerated growth of phytoplankton is within the capacity of grazers and that increased productivity in the lower James River estuary is accumulating in higher trophic levels. The only evidence for this is the

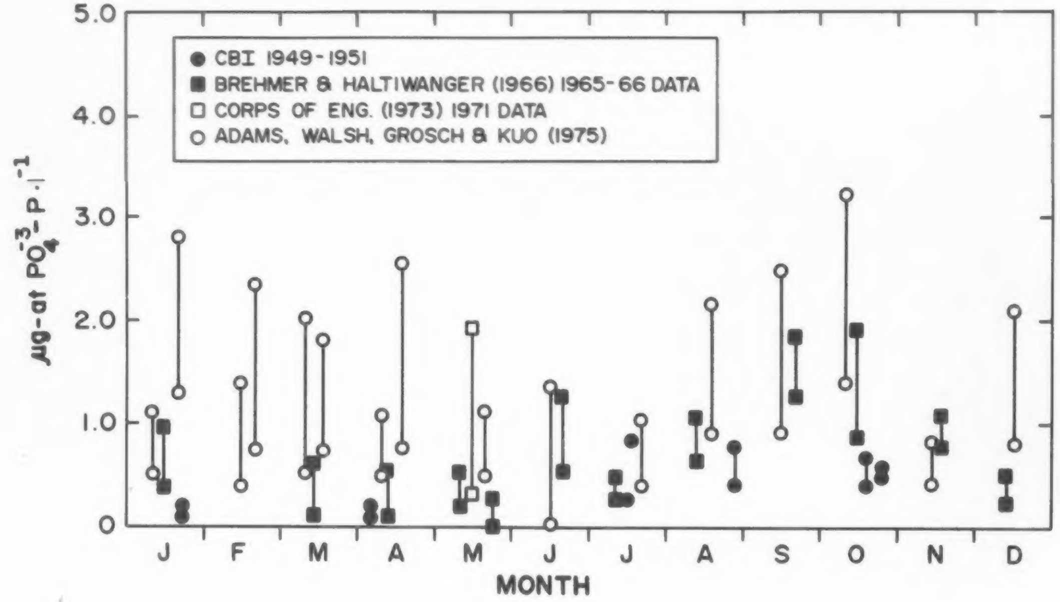


Figure C-28. Concentrations of orthophosphate-P in the lower James River.

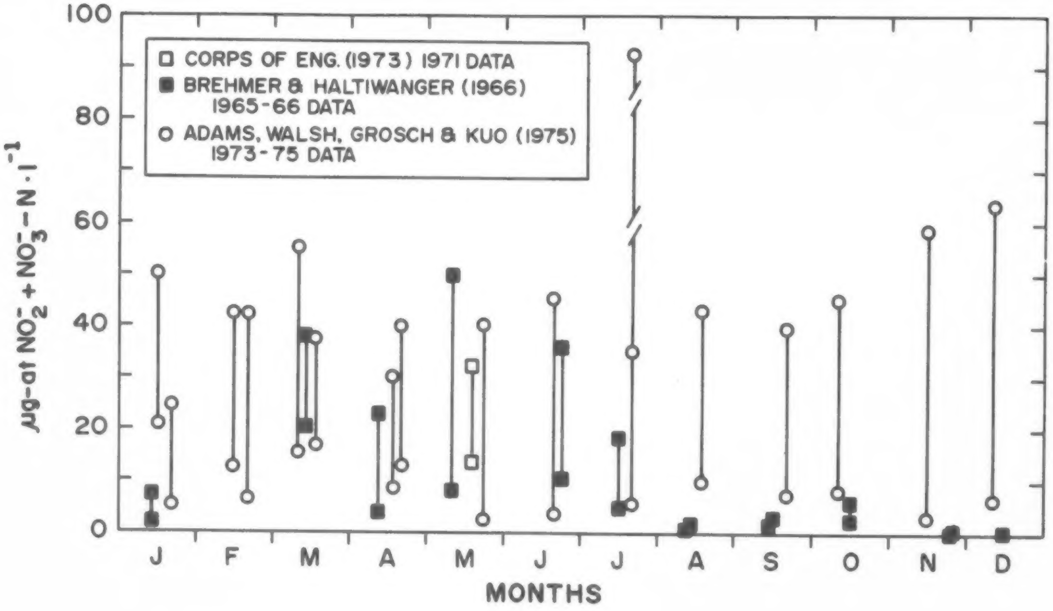


Figure C-29. Concentrations of nitrate plus nitrite-N in the lower James estuary.

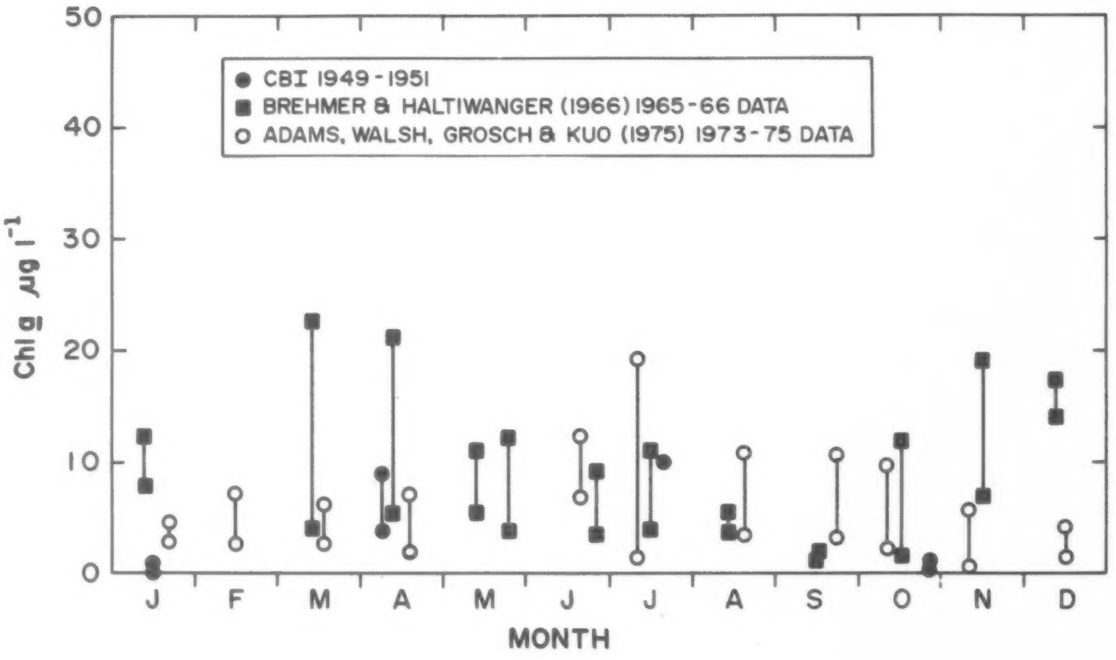


Figure C-30. Concentrations of chlorophyll a in the lower James estuary.

dramatic increases in catches of menhaden in recent years (Chapter D).

The lower James is relatively turbid, compared to portions of Chesapeake Bay with comparible salinities, but no more so than the lower reaches of other tributaries where increased nutrients have resulted in higher concentrations of chlorophyll. Turbidity however has been suggested by a number of people (in the form of personal communication) as a possible reason for the relatively low concentrations of chlorophyll in the lower James.

The most dramatic effects of enrichment in the James River are apparent in the upper reaches. Unfortunately we have no good record of historical trends as changes apparently occurred prior to the first studies of the River.

OTHER TRIBUTARIES TO THE LOWER BAY

The York and Rappahannock Rivers were sampled occasionally for phosphorus, turbidity and chlorophyll a during the C.B.I. studies in 1949-1951 (Stroup and Wood, 1966). Table C-7 shows the ranges of orthophosphate-P and chlorophyll a observed in 1949-1951. The seasonal pattern of phosphorus concentrations was different from the lower James River during the same period in that during July through October in the York and during July in the Rappahannock there were relatively high concentrations of phosphorus in surface waters, but rarely in excess of 1.0 ug-at l^{-1}. Data presented in Appendix B of the Existing Conditions Report (U.S.A. Corps of Eng., 1973, Table B-XI-49) indicate concentrations of 1.6 to 16 ug-at l^{-1} during February, April, May and September in the Rappahannock during 1970.

Table C-7. Ranges of concentrations of orthophosphate-P (ug-at l^{-1}) and chlorophyll a (ug l^{-1}) from the lower York and Rappahannock Rivers during the 1949-1951 studies by C.B.I.

Dates	York		Rappahannock	
	PO_4^{-3}-P	Chl a	PO_4^{-3}-P	Chl a
1 July-3 Aug., 1949	1.0-3.0	—	0.8-2.0	—
18 Aug.-6 Sept.	0.8-3.0	--	0.2-0.4	--
10-25 Oct.	0.7-0.8	—	$0.3^{\pm}$	--
25 Mar.-25 Apr., 1950	0.1-0.2	4	0.1-0.2	6-8
20-25 May	0.0-0 + 1	4	0.0-0.1	3-8
14-19 July	$0.2\text{-}0.2^{+}$	5-9	0.1-0.3	$4\text{-}9^{+}$
14 Oct.-2 Nov.	$0.7\text{-}0.9^{+}$	$1\text{-}1^{+}$ 0-1	0.3-0.4	$1\text{-}6^{+}$
10-23 Jan., 1951	0.1-0.2	—	0.0-0.1	$1\text{-}7^{+}$
21-31 May	0.44	—	0.16	--

In the York River, concentrations ranged from 1.6 to 3.2 ug-at 1^{-1} during the same period (U.S.A. Corps of Eng., 1973, Table B-XI-52) (data taken from Pheiffer, Donnelly and Possehl, 1972). The number of observations listed in the Existing Conditions Report were somewhat fewer than in the C.B.I. data (Table C-7) but increased concentrations of phosphorus are indicated. The Virginia Water Quality Control Board (1976) shows that during 1968-1971 5.5 percent of stations sampled in the Rappahannock River had concentrations of orthophosphate-P in excess of reference standards. In 1972 to 1975 3.4 percent of the samples exceeded the standards. The reference level for orthophosphate-P is 3.2 ug-at 1^{-1}, a concentration considerably higher than those observed in the Rappahannock in 1949-1951 (Stroup and Wood, 1966). In the York River, the Virginia State Water Quality Control Board (1976) observed no phosphorus concentrations in excess of the relatively high reference levels.

Chlorophyll a concentrations in the lower York River estuary are considerably higher in recent years (Haas, Hastings and Webb, 1980) than were observed in 1949-1951 (Table C-7). Neither the Corps Report (U.S. Corps of Eng., 1973) or the Virginia 305b report (Va. State Water Quality Control Board, 1976) provide data on concentrations of chlorophyll for comparison with the earlier data.

In recent years visible blooms of dinoflagellates ("red water") have occurred in the lower York River and other tributaries. There were large year-to-year variations in the frequency and duration of these blooms (Zubkoff and Warrinner, 1975) but they were not frequently noted in earlier years. Neilson (1978) commented that diurnal fluctuations in concentration of oxygen, an indication of increased community metabolism, have been noted in recent years. The periodic low concentrations of dissolved oxygen observed recently in the lower York River (Haas, 1977; Webb and D'Elia, 1980; D'Elia, et al., 1980) were not observed often in the earliest data available; the C.B.I. data for 1949-1961 (Hires, Stroup and Seitz, 1963). Concentrations of dissolved oxygen were less than 2 ppm in bottom waters of the York River on only one of nine occasions when measurements were made during the months of July, August, and September. In recent years there are protracted periods when bottom waters are low in dissolved oxygen.

There are insufficient data to establish trends for concentrations of nitrogen in the York and Rappahannock Rivers. But it appears that phosphorus and chlorophyll a have increased in the lower estuaries. It has been shown, however, that considerable short-term variations in concentration occur for both N and P (Webb and D'Elia, 1980). These variations are due to hydrographic processes.

A number of the smaller tributaries to the Bay in the Hampton Roads-Norfolk area have been surveyed in recent years (Neilson, 1978). Many show severe effects of enrichment, but receive huge amounts of effluent and non-point runoff relative to their volumes. There are dense algal blooms and periods of low oxygen concentrations in several of the smaller tributaries including the Elizabeth, Back and Poquoson Rivers.

The data base for the smaller tributaries of the lower Bay in part reflects the first preception of problems. Discharges that are high in B.O.D. in the freshwater portions of the larger tributaries have been the first order of concern. More attention needs to be given in future studies to seasonal, monthly and weekly variations in nutrients and distribution of chlorophyll *a*, and the vertical distribution of dissolved oxygen in the stratified portions of the estuaries.

SUMMARY OF WATER QUALITY TRENDS

The changes that have been observed in concentrations of nutrients and chlorophyll *a* in various parts of the Bay can be explained in a way that conforms to the conceptual model presented by Webb (1980). Figure C-31 shows the box model from Figure 2 of Webb (1980). The most important feature of the conceptual model is that increased inputs of nutrients or organic carbon result in increased *flows* of material and energy through the Bay ecosystem. There may, or may not, be increases in the sizes of the compartments, i.e., the standing stocks of the components such as nitrogen, phosphorus, algae, fish, etc. Changes in rates of flow through an ecosystem would be undetected by most routine studies of water qualtiy, which sample only standing stocks.

Few of the studies we reviewed included measurements of rates of transfer through trophic levels of the Bay ecosystem. Those that did usually only measured rates of primary productivity. The following comparisons of effects of enrichment on various parts of the Bay, therefore, begin with the assumption that increased inputs of nutrients or carbon to a portion of the Bay cause increased rates of flow of nutrients and energy through the biota. Increases in standing stock are taken to mean either that the size of a compartment has increased to accommodate higher flows, or that flow out has decreased, causing accumulation within a particular component.

There are clearly different results from the additions of nutrients to various parts of the Bay and its tributaries. Table C-8 shows a summary of the changes observed in three major components of the Bay ecosystem, phosphorus, nitrogen, and algae, represented by chlorophyll *a*.

In the upper Bay, concentrations of phosphorus have increased, concentrations of nitrogen have remained unchanged and chlorophyll has increased. The loading trends developed by E.P.A. suggest that inputs of both nitrogen and phosphorus to the upper Bay are increasing (Guide and Villa, 1972). It appears that virtually all of the additional nitrogen is either presently passing through the nutrient pool into other components of the ecosystem, or is being lost through processes such as denitrification (Kaplan, et al., 1978; Elkins, 1978; McElroy, et al., 1978; Elkins, Wofsy and McElroy, 1980). The seasonal pattern previously shown by concentrations of phosphorus in the upper Bay no longer occurs. Concentrations of phosphorus are now variable but, in aggregate, uniform all year in the upper Bay. Jaworski (1980) has concluded that based on ratios of nutrients in inputs to the upper Bay, phosphorus should be limiting. However, in our opinion the historical trends suggest that nitrogen is the more likely limiting nutrient at present. The upper Bay is relatively turbid and it is quite likely that low light intensity often limits algal production. There is evidence that some species of algae grow at lower light intensities in the presence of

Table C-8. Summary of changes in concentrations of nutrients and chlorophyll a in various parts of Chesapeake Bay. Underlined statements show where relatively large changes have occurred.

	PO_4^{-3}-P	$NO_3^- + NO_2^-$-N	Chlorophyll a
Upper Bay	Increased	Unchanged	Increased
Middle Bay	Increased	Insufficient Data	Increased
Lower Bay	Increased	Insufficient Data	Unchanged
Patuxent River			
Upper	Increased	Increased	Increased
Lower	Increased	Increased	Increased
Potomac River			
Upper	Data started too late	Data started too late	Increased
Lower	Increased	Insufficient Data	Increased
Rappahannock and	Increased	Insufficient Data	Increased
York Rivers	Increased	Insufficient Data	Increased
James River			
Upper	Data started too late	Data started too late	Increased
Lower	Increased	Increased	Unchanged or decreased

TYPING GUIDE SHEET
EPA-287 (Cin.)
(4-76)

higher concentrations of nutrients, however, and the relationships between light, nutrients and algal production in the upper Bay are likely to be complicated and variable with time. Our perception of nutrient limitation in the upper Bay has recently been made more complicated by the discovery by Loftus, Place and Seliger (1979) that dinoflagellate blooms initiated by nutrient pulses from land runoff may become carbon-limited in the upper Bay. The role of inorganic carbon in these cases is to prolong the duration of the blooms, and presumably, increase the total production of a bloom. The occurrence of blue-green algae in areas of low or no salinity, and the possibilities of nitrogen fixation and secondary effects on consumers further complicate the interpretation of events in the upper Bay.

The effects of enrichment in the middle Bay are modest (Table C-8). Early signs of change are present in the form of slightly higher concentrations of phosphorus and increased concentrations of chlorophyll. No one has yet determined whether the decreased transparency of waters in the middle Bay, apparently caused by increased phytoplankton, has partly offset the presumed increases in primary production indicated by the higher standing stocks of algae.

There are some indications that increased algal production and the now common occurrence of dinoflagellate blooms in the middle Bay are having an effect on the intensity of the deep water D.O. minimum. There are major effects of altered D.O. regimes on remineralization from the sediments (Webb and D'Elia, 1980), a process which may in turn be driven by rates of deposition of particulate organic matter to the sediments (Boynton, Kemp and Osborne, 1980).

The lower Bay appears to be relatively unaffected by nutrient inputs. Only phosphorus has increased slightly. The reasons for the slight impact of added nutrients on the lower Bay may be two-fold. First, the exchanges of water across the Bay mouth are large and dilution, therefore, great. More importantly, nutrients added to the upper Bay and tributaries, particularly nitrogen, release phytoplankton from nutrient limitation. The nutrients are then incorporated into particulate forms and trapped within the region of utilization by the two-layered circulation of the Bay. Evidence from the tributaries suggests that as algal stocks increase, light becomes more important as a limiting factor and nutrients pass further downstream before being incorporated into biomass. Increased (over conditions in 1949-1951) algal production probably now extends below the Potomac River in the mainstem of Chesapeake Bay.

There are increased concentrations of both major nutrients and of chlorophyll *a* in all parts of the Patuxent River estuary. There appears to have been a downstream progression with time of areas with increased concentrations of chlorophyll *a*.

Because of the extent of the data base in the Patuxent River estuary (Appendix B), some of which we did not obtain, that system provides the most well documented example of the effects of enrichment in a Bay tributary. As nutrient concentrations increased in the upper, turbid portion of the Patuxent, chlorophyll *a* increased somewhat. Ambient concentrations of nutrients are now relatively high all year in the upper Patuxent, suggesting light limitation of primary production. Episodes of low concentrations of D.O. in the upper Patuxent appear to be related to high concentrations of particulate carbon, but not chlorophyll. Increased nutrient concentrations in the lower, two-layered part of the Patuxent have been paralleled by large increases in maximum concentrations of chlorophyll and decreases in transparency of the water during the summer months. Increased variations in concentrations of D.O. in surface waters and extended periods of near anoxia in bottom waters which now occur were not observed in earlier studies. There have been reports of mortalities of benthic animals and effects on commercial fisheries that are caused by reduced concentrations of oxygen. Ratios of nitrogen to phosphorus are low in the inputs to the Patuxent (Jaworski, 1980), in the nutrients remineralized by the benthos (Boynton, Kemp and Osborne, 1980) and in the water column during the summer months. Data taken during the late 1930's suggest that natural dissolved phosphorus concentrations in surface waters were high enough to support the algal standing stocks presently being observed. The fact that phosphorus regeneration from the sediments is enhanced by increased organic production (Nixon, 1980; Boynton, Kemp and Osborne, 1980) and further enhanced by reduced concentrations of D.O. (Webb and D'Elia, 1980) suggests that algal production in the lower Patuxent could not be reduced by controlling phosphorus in the watershed. Some nitrogen appears to be lost from the Patuxent through denitrification at present (the nutrient budget cannot be balanced) (Mihursky and Boynton, 1978; Boynton, Kemp and Osborne, 1980). During early studies, concentrations of nitrate and nitrite were very low during the summer months, and still become quite low at times, suggesting that nitrogen control would reduce algal production.

The apparent high dependence of phytoplankton on recycled nitrogen during the summer months in the Patuxent (Boynton, Kemp and Osborne, 1980) suggests that *total annual input* rather than seasonal inputs are controlling the magnitude of primary production. This hypothesis has been proposed previously for coastal waters in general (Smayda, 1976). Thus, seasonal removal of nitrogen would be less effective than year-round control, unless it were specifically known that seasonal pulses of nutrients passed through the system unassimilated.

The changes that have occurred in the Patuxent are likely to progress further as loading increases with population growth in the basin. Similar changes could be expected with urbanization of other medium-sized tributaries of the Bay.

The extensive studies of the Potomac estuary show that the earliest problems were with high B.O.D. in untreated and treated sewage. Recognition of changes brought about by nutrient additions did not occur until after the advent of dense algal blooms. Nutient and chlorophyll concentrations were not measured early enough in the upper Potomac to document changes.

Increased production of algae in the Potomac is now occurring in the lower reaches, but the concentrations of chlorophyll *a* are still generally lower than the earliest observations from the Patuxent. The area in the Potomac where the next major changes might occur is between river miles 30 to

50, the usual upper limits of salt intrusion. During one year of the 1969-1971 E.P.A. studies concentrations of chlorophyll well in excess of 60 ug l^{-1} were reported for that area (Jaworski, et al., 1972), but concentrations were generally below 35 ug l^{-1}.

The uncertainty over nutrient limitation in the Potomac was mentioned previously. Work presently underway on the Potomac by E.P.A., the State of Maryland, and the U.S. Geological Survey may help resolve the issue. An empirical example which may be applied to the upper Potomac, or the low-salinity turbid areas of any Bay tributary is available in the Pamlico River estuary in North Carolina. The Pamlico is heavily loaded with phosphorus from commerical mining operations but has relatively little external input of nitrogen, only about 5 percent of the annual phytoplankton needs (Kuenzler, Stanley and Koenings, 1979). Phytoplankton production and standing crops, which are modest (and similar to the pre-perturbation conditions in the Patuxent) are sustained by nitrogen recycled within the system. We suspect that tributaries to Chesapeake Bay, including the Potomac, might be functionally similar to the Pamlico estuary, given an excess of phosphorus without large amounts of added nitrogen. However, the role of nitrogen fixers (blue-green algae) and the conditions that promote their development in some tributaries (e.g., the Potomac, James and some areas in the upper Bay) but not in others (e.g., the Patuxent, York and Rappahannock) needs to be better understood before nutrient limitations can be understood with certainty.

The Rappahannock and York Rivers have both experienced increases in concentrations of phosphorus and chlorophyll _a_ (Table C-8). Our data were not sufficient to establish trends for nitrogen. The changes in the lower reaches of both Rivers appear to be similar to those occurring in the Patuxent. Minimum concentrations of dissolved oxygen in bottom waters of the lower York River have decreased, but secondary effects are not well known (but see Neilson and Cronin, 1980).

The processes involved in the periodic anoxia in the lower York Estuary are complicated (Haas, 1976; Webb and D'Elia, 1980; D'Elia, Webb, Wetzel, 1980) and result in cyclic changes in rates of remineralization of nutrients from the sediments. The variability in rates of remineralization demonstrated by the studies on the lower York River is extremely important as it illustrates the tenuity of steady-state models currently used to predict estuarine water quality by management organizations (e.g., see Salas and Thomann, 1976 or more recent examples in O'Connor, 1980). Where cyclic changes have important effects on ecosystem function a good fit by a steady-state model should probably be considered merely fortuitous, and of little predictive value.

Changes in the upper James estuary have essentially paralleled those in the Potomac, but have been less well documented. Industrial effluents and their B.O.D. are more important in the James, but the systems are otherwise similar.

The changes that have occurred in lower James (Table C-8) are perhaps the most interesting that we have encountered. There have been increases in

EPA-287 (Cin.)
(4-76)

both major nutrients without concurrent increases in chlorophyll a. It has been suggested that dilution is a major factor in the maintenance of the lower James in a relatively unaltered state (Neilson, 1978). It is difficult to see, however, how dilution can account for the relatively low concentrations of chlorophyll a in the presence of increased nutrients. We proposed earlier in the chapter that the conditions in the lower James could fit the conceptual model proposed by Webb (1980) (Fig. C-31), if increased flows through the primary producers were accumulating in other compartments (trophic levels). If that were the case, one might expect effects of increased production to be manifested in the concentrations of dissolved oxygen in the bottom waters of the lower James, a two-layered estuary. Low concentrations of D.O. in bottom waters have been detected in recent years during studies conducted by the V.I.M.S. (published in: Corps. of Eng., 1973). Unfortunately, the early data base does not allow the establishment of trends with certainty, but there were no instances when D.O. concentrations were less than about 3 ppm in the early studies by C.B.I. (Hires, Stroup and Seitz, 1963). Periodic monitoring of dissolved oxygen should be continued in the lower James. It would also be extremely useful to have some recent measurements of rates of primary production and respiration from the lower James or the lower Bay that are directly comparable to the early work done by Patten, et al. (1963).

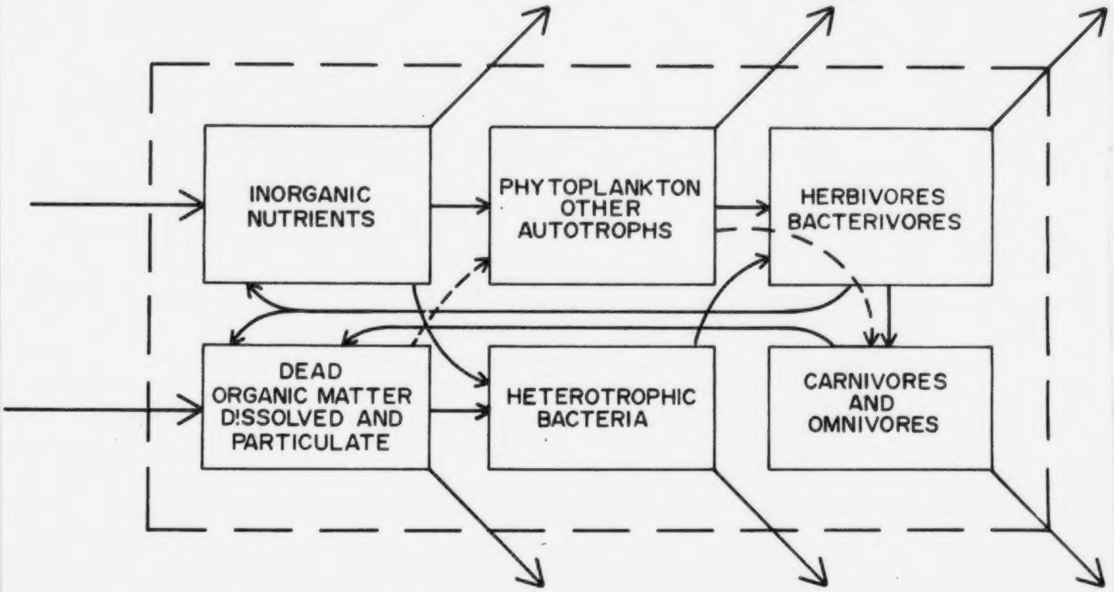


Figure C-31. Box diagram of conceptual model proposed by Webb (1980).

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

CHAPTER D

COMMERCIAL FISHERY PRODUCTION

At the beginning of our efforts to document the effects of excessive enrichment on commercial fishery yields we were aware that variations in at least two important fisheries, oysters (Ulanowicz, Caplins and Dunnington, 1980) and striped bass (Merriman, 1941; Heinle, et al., 1976; Boynton, Setzler, Wood, Zion, Homer and Mihursky, 1977; Van Winkel, Kirk and Reist, 1979) were closely correlated with variations in climate. In the Gulf of Maine (Sutcliffe, Drinkwater and Muir, 1977), and in other coastal areas, Sutcliffe (1972) proposed mechanisms by which climatic variations affect commerical fisheries through variations in nutrient inputs and subsequent primary production. Jeffries and Johnson (1974) proposed an effect of temperature on larval flounder in Narragansett Bay which explained much of the subsequent variation in commerical catch.

For the foregoing reasons, we felt that an analysis of the effects of climatic variation on commercial landings was imperative before the effects of excessive enrichment could be evaluated. The funding provided for this task was largely consumed by the compilation of the data base. The format of the National Marine Fisheries Service (N.M.F.S.) data base (catches broken down by county or water area) was not appropriate for distinguishing Bay-wide trends. We modified the N.M.F.S. data base to permit comparison of trends in landings with time for Maryland and Virginia, or for both states combined, excluding coastal catches. Following this effort, funding was not available for extensive analyses, however some our colleagues were able to use the data base in Appendix C to analyze the effects of climatic factors on commercial landings in Maryland. A paper has been prepared for publication (Ulanowicz et al., ms. submitted) and appears as Appendix D. Maryland catch statistics were used in the analysis because of the specific interest of the authors. The separate catch statistics for the Virginia portion of the Bay are available in our data base (Appendix C) and are used in the remainder of this Chapter, which introduces some qualifications concerning the masking of possible effects of enrichment by variations in climate which have periodicities in excess of the time scale of changes we perceive to be caused by enrichment of Chesapeake Bay.

LONG TERM TRENDS OF FUNCTIONAL GROUPS OF FISH

The paper by Ulanowicz et al. (ms. submitted) describes a number of remarkably good correlations between climatic variables and commercial fishery landings. A simple correlative approach to the analysis of fishery data introduces a serious hazard of discovering good correlations which cannot be explained biologically. We attempted to determine the best time lag to use for a simple correlation between commercial landings of five

BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
EPA-287 (Cin.)
(4-76)

anadromous species and deviation from January and February mean air temperature. The catch of one of the species tested, striped bass, is known to be inversely related to deviations from winter temperatures (Merriman, 1941; Heinle, et al., 1976). We postulated that other anadromous fishes might be affected by the same variation in food resources thought to affect striped bass. In addition, we hoped that variations in the simple correlation coefficient as a function of time lag would indicate the age at which a given species had the greatest impact on the commercial landings. Table D-1 shows that the catch of striped bass and white perch were strongly and inversely correlated with deviations from long-term average winter temperatures, regardless of time lag of 1-8 yrs, indicating a relationship to cold winters. The catch of alewives was positively correlated at all time lags. The catches of gizzard shad and American shad were not correlated to winter temperatures at time lags of 1-4 yrs but were at lags of 5-8 yrs. As American shad mature at an average age of 4-5 yrs (Jones, Martin, and Hardy, 1978), the time lag for the correlation seems logical. Gizzard shad, however, mature in 2-3 yrs (Jones, et al., 1978) making the highly significant correlations at 6 and 7 yrs difficult to explain. The correlation coefficients for striped bass were highest at 2 and 3 yrs lag, concurrent with the age of entry into the commercial catch. The continuing high correlations for that species may reflect the continued effects of dominant year-classes on the fishery.

Table D-1. Correlation coefficients between commercial landings of five species of anadromous fish and deviations from average winter temperatures with time lags of 1-8 years.

	Time Lags (yr)/Correlation Coefficients							
Species	1 N=49	2 N=48	3 N=47	4 N=46	5 N=45	6 N=44	7 N=43	8 N=42
Alewife	.476	.388	.326	.347	.388	.499	.513	.471
American Shad	.098	.015	.026	.166	.242	.236	.282	.328
Striped Bass	-.464	-.590	-.565	-.445	-.325	-.301	-.328	-.274
White Perch	-.409	-.375	-.441	-.462	-.389	-.309	-.382	.273
Gizzard Shad	.133	.020	.019	.072	.263	.444	.341	.124

Another quite plausable explanation for the small effect of time lag on the correlation coefficients for alewives, striped bass and white perch may lie in the autocorrelation of climatic variables. Heinle, et al. (1977) noted that poor and good years for the striped bass fishery were clustered, i.e., periods of several poor years alternating with periods of several good years as shown by Figure 4 of the paper by Ulanowicz, et al. (ms. submitted, see Appendix D). These may in fact be related to long-term (20-22 yr) climatic cycles (Van Winkle, et al., 1979) which are themselves correlated with solar cycles (Mock and Hibler, 1976; Hibler and Johnson, 1979). The period of the cycle shown for soft-shelled claims in Figure 3 and for striped bass in Figure 4 of the paper by Ulanowicz, et al. (ms. submitted) is approximately 20 yr, noted also by Van Winkel, Kirk and Reist (1979) and in Figure A-1.

If effects of cultural activities, such as excessive enrichment, on commercial landings have occurred only relatively recently (since about 1965-1970 for effects of trophic changes in most of the Bay; Chapter C), and the direction of the changes they cause matches the long-term cycles, those cultural effects would be dificult to detect. Landings of striped bass and American shad in Chesapeake Bay are now at all-time lows. We cannot yet tell whether this is within the range of natural variation, or is an effect of man. Note that during the same period, freshwater flows to the Bay have been higher than average, and salinities lower (Chapter A).

We suspected that factors affecting the success of one spring spawning anadromous species might similarly influence other anadromous species which spawn in the spring. As can be seen in Chapter C, the greatest effects of enrichment of the Bay occur in the low salinity areas. Total catches in Chesapeake Bay of four anadromous fish, alewife, American shad, striped bass and white perch, were compared with total landings of seven species which spawn in marine waters, bluefish, croaker, flounder, scup (porgy), seabass, seatrout (weakfish) and spot from 1952-1975 and are plotted in Figure D-1. Prior to the decade of the 1970's, the lowest total landings of the anadromous group were 530 million pounds, occurring in 1960. The highest landings were about 45-50 million pounds in 1965, 1967 and 1968. Since 1969 the landings of the anadromous group have declined to a series of new lows in 1971-1975 of about 20 million pounds. Landings of the marine group were highest in the late 1950's, and lowest in 1969. The trend for the marine group has been generally upward since 1969, but not to previous high levels. There is a rough inverse relationship between the catches of the marine group and the anadromous group up to 1970 (Fig. D-2). After 1970 the decreased landings of the anadromous group are not offset by proportional increases in landings of the marine group.

The total landings for Chesapeake Bay are completely dominated by menhaden (Fig. D-3). Note that menhaden catches in recent years have been 300-500 million pounds versus about 30 million pounds for all other fish. Menhaden catches fluctuated between 100 and 200 million pounds annually between 1930 and 1952. They then rose to between 200 and 350 million pounds annually through 1969 and then rose again to present high levels, fluctuating around 400 million pounds annually (Fig. D-3).

Menhaden occupy a relatively low trophic level, feeding primarily on zooplankton and on phytoplankton larger than 20 um in diameter (June and Carlson, 1971; Durbin and Durbin, 1975). Increasing planktonic production and standing crops (Chapter C) might thus favor menhaden. The increased catches of menhaden from 1970 onwards coincide in time with some of the observed changes in the Bay that suggest increased production of plankton. It is not clear from our historical review of water quality that the dramatic

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

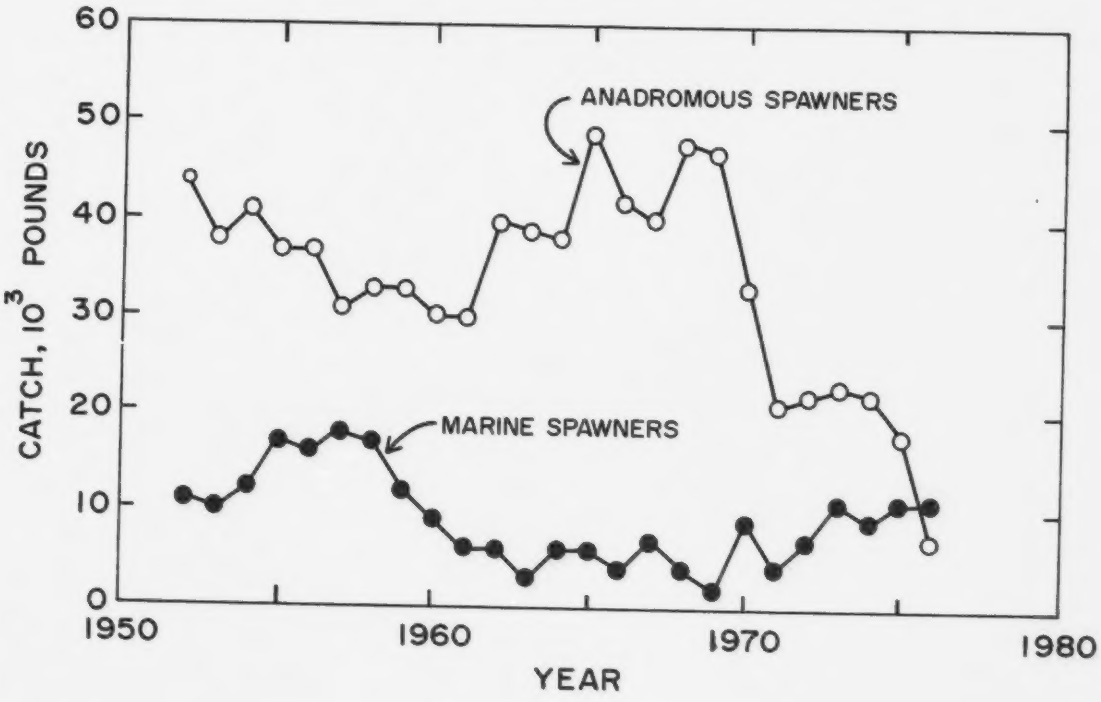


Figure D-1. Landings in Chesapeake Bay of anadromous fish and marine spawners (see text for species included) versus time.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 267)
TYPING GUIDE SHEET

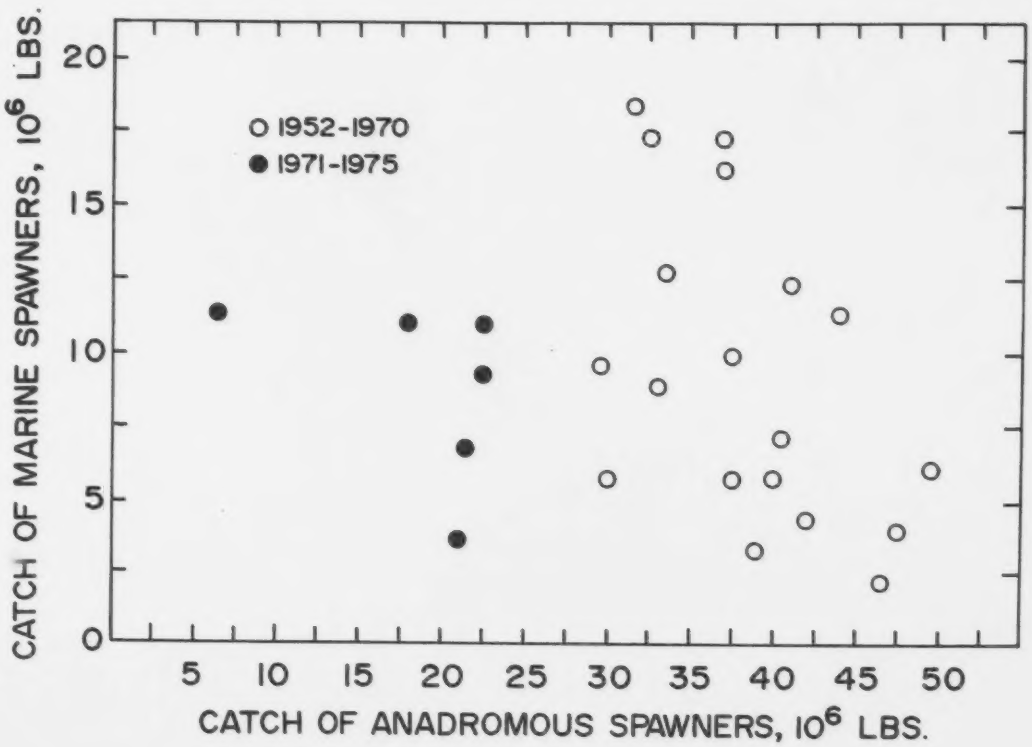


Figure D-2. Relationship between catches of marine-spawning versus anadromous fish in Chesapeake Bay.

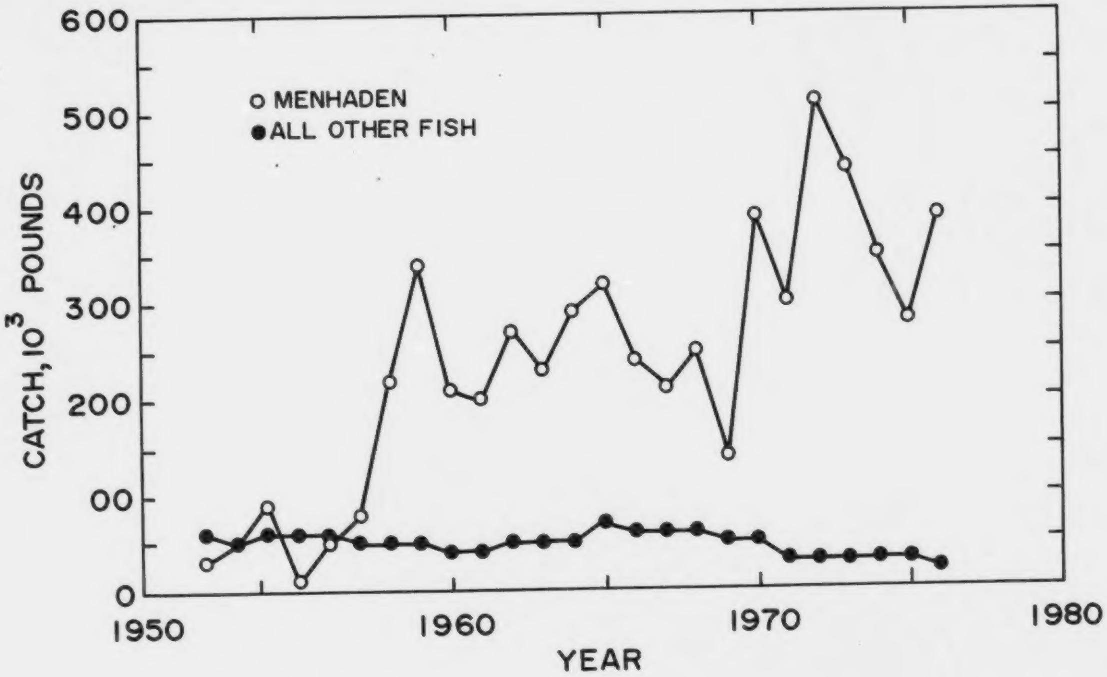


Figure D-3. Catches of menhaden in Chesapeake Bay as a function of time.

EPA Form 2350-4 (4-80)
TYPING GUIDE SHEET

increase in catches during the early 1950's was accompanied by any change in planktonic production.

Given the increases in catches of menhaden, we examined the trends for commerical landings grouped by trophic level. Fish were assigned to three groups: planktivores, top carnivores, and invertebrate carnivores (Table D-2), based on general knowledge of the fisheries staff at the Chesapeake Biological Laboratory, our knowledge of the literature, and an ongoing project on food habits of fishes in Chesapeake Bay (Homer and Jones, pers. comm.). In the Maryland portion of Chesapeake Bay, catches of planktivores have remained relatively constant since the early 1950's (Fig. D-4). Declines in catches of anadromous planktivores such as American shad and alewives (see Ulanowicz, et al., ms. submitted, Appendix D) since 1969 have been offset by increases in catches of menhaden in the upper Chesapeake Bay. Landings of top carnivores and invertebrate carnivores have been declining slowly (Fig. D-4). In the lower Bay menhaden completely dominate the planktivorous category. Catches of menhaden have increased as discussed previously. Catches of top carnivores and invertebrate carnivores have declined (Fig. D-5) in a pattern similar to that seen in the upper Bay (Fig. D-4).

Table D-2. Trophic groupings of Chesapeake Bay fishes. Generic and specific names indicate dominants in the catches but are not all-inclusive. Common names are as reported in the National Marine Fisheries Service data base.

Planktivores	Invertebrate Predators	Top Carnivores
Alewife	Blackdrum	Bluefish
Alosa pseudoharengus	*Pogonias cromis*	*Pomatomus saltatrix*
American Shad	Catfish and Bullheads	Flounders
Alosa sapidissima	*Ictalurus spp.*	*Pseudopleuronectes americanus*
Atlantic Menhaden	Croaker	Seabass
Brevoortia tyrannus	*Micropogon undulatus*	*Centropristes spp.*
Butterfish	Eels	Striped Bass
Peprilus triacanthus	*Anguilla rostrata*	*Morone saxatilis*
P. alepidotus	Scup	Weakfish
Gizzard Shad	*Stenotomus chrysops*	*Cynoscion regalis*
Dorosoma cepedianum	Swellfish	
	Sphaeroides maculatus	
	Spot	
	Leiostomus xanthurus	
	White Perch	
	Morone americanus	

SUMMARY

There has thus been a Bay-wide decrease in anadromous spawners from about 1969 onwards, including planktivorous species (Fig. D-1) when menhaden are not included. Catches of menhaden have increased from 1969 onwards.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 297)
TYPING GUIDE SHEET

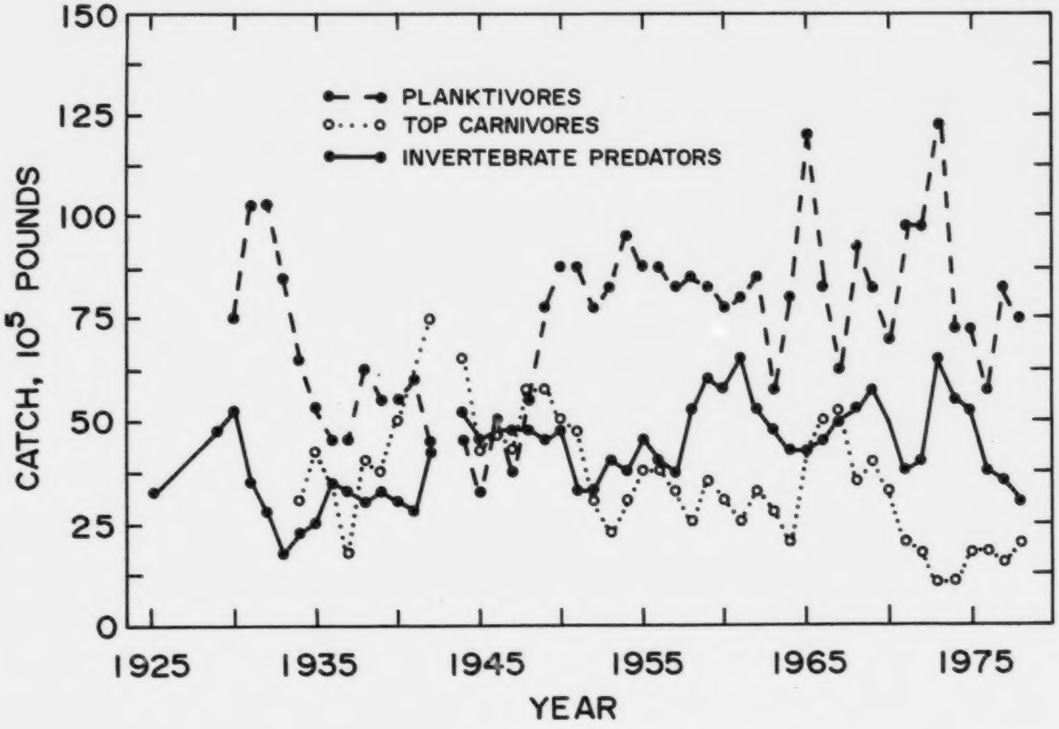


Figure D-4. Catches of selected trophic groups of fish in Maryland (cf. Table D-2).

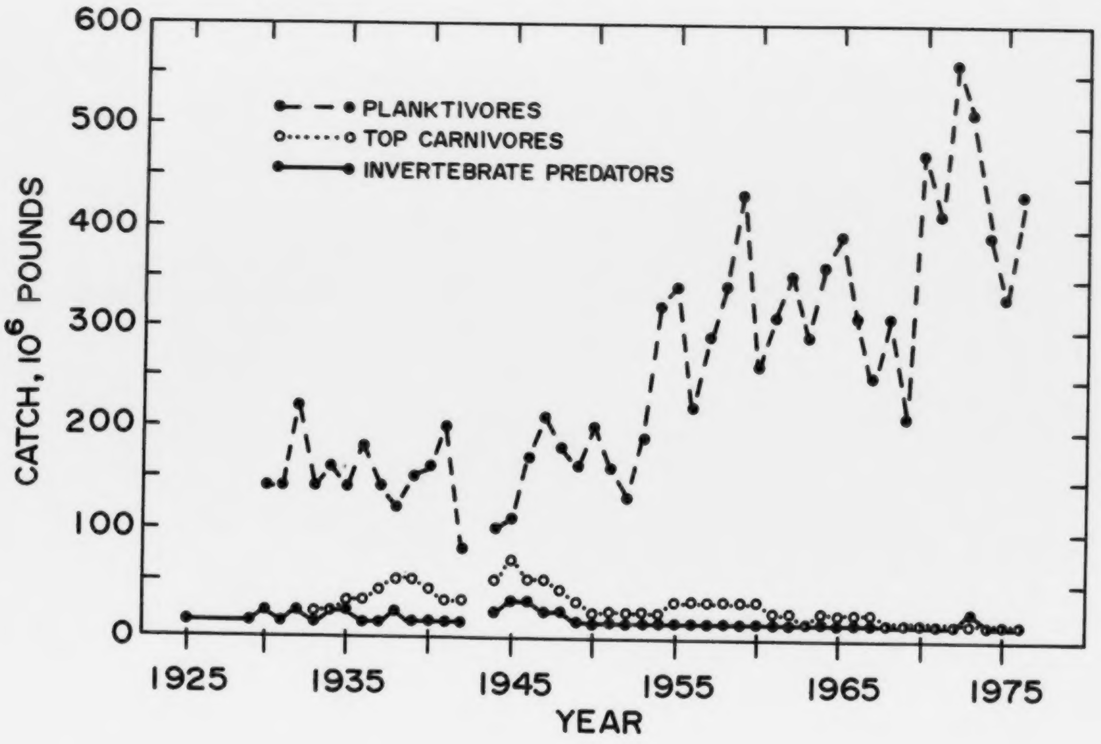


Figure D-5. Catches of selected trophic groups of fish (cf. Table D-2) in the Virginia portion of Chesapeake Bay.

EPA Form 2350-4 (4-80)
TYPING GUIDE SHEET

Increases in catch (and presumably abundance) of one top carnivore, bluefish, have been more than offset by decreases in an anadromous top carnivore, striped bass. In a general way, the fish population in Chesapeake Bay is becoming more dominated by planktivores, with diminished numbers of invertebrate predators and top carnivores (Figs. D-4 and D-5). However, it cannot be safely concluded that this represents the sort of shift in community structure that is known to occur in other ecosystems as a result of excessive enrichment (Webb, 1980). As mentioned previously, the period during which the Bay has experienced apparent changes in trophic state, from the mid-1960's onward, may coincide with the half cycle for natural variations in abundance. If species whose abundance might be expected to increase naturally (e.g., striped bass, alewives and soft-shelled clams; c.f. Ulanowicz, et al., ms. submitted) do not do so in the next few years, we may more strongly believe that permanent changes have occurred.

The full historical record of commercial landings for Chesapeake Bay, and the ocean side of Maryland and Virginia is available through the University of Maryland, Computer Science Center. Documentation for the use of the fisheries data base is in Appendix C.

CHAPTER E

THE CURRENT STATUS OF CHESAPEAKE BAY WITH RESPECT TO ENRICHMENT

"Trophic state" like "water quality" is a relative and vague term, which may mean different things to different people under different circumstances. Consequently, there is no simple, universally applicable scale of "trophic state" that can be used to assess qualitatively or quantitatively the current status of the Chesapeake Bay with respect to nutrient enrichment. We will therefore base our assessment of this status on those determinants of "trophic state" and "water quality" that most frequently come to the minds of experts and laymen when they are asked to consider the meaning of the terms.

Oxygen concentration is certainly the single most important determinant of "water quality" to many people. Inasmuch as oxygen concentration is often dependent on the "trophic state" or standing stock and partitioning of organic matter in the water body in question, carbon budgets are particularly important to understand. In the Chesapeake estuary, there is considerable variation in the nature of carbon budgets from place to place. Biggs and Flemer (1972) found that about 90% of the organic carbon in the upper Bay was allochthonous, i.e., derived from outside the system. In contrast they found that in the middle Bay about 97% of the annual budget of organic carbon was derived from autochthonous or local production by phytoplankton. Similar increases in the production of phytoplankton, stimulated by added nutrients, might thus have quite different relative effects in the two areas. Perhaps a useful approach would be to segment the Bay into functionally similar units with similar characteristics and manage the throughput of organic material to control ultimate oxygen demand (as proposed by Clark and Roesch, 1978, for the upper Potomac). A preliminary segmentation for this purpose has been accomplished by Ulanowicz and Neilson (1974). Effective use of such allocations of ultimate oxygen demand would, in our opinion, require considerably better information on biological and chemical interactions in the Chesapeake Bay system and in the selected segments.

The conceptual model proposed by Webb (1980) suggests that the trophic state of an ecosystem can theoretically be changed by increasing throughput of materials and energy in the system without increasing the quantity (standing stock) of any of its components. Ulanowicz (1980) has proposed that flows or rates of exchange between components of an ecosystem provide a good measure of the trophic state. Rates of exchange or fluxes are commonly measured only for primary producers, and sometimes estimated for selected consumers. Ulanowicz's concept of using flux rates to characterize trophic state appears worthy of future consideration.

A candidate index for trophic states of estuaries, developed as part of

EPA-287 (Cin.)
(4-76)

this project (McErlean and Reed, 1979) has yet to be tested. It or one like it may prove to be a useful tool for indicating future and past changes in trophic state of Chesapeake Bay. We believe that such indices will be most useful in identifying problem areas and conditions for more intensive study, but are of limited usefulness in providing managers with specific courses of action to correct the problems.

Although there are no simple, universal indicators of trophic state or of the status of the Bay as a whole, increased primary production is an important factor and is *usually* indicated by some increase in algal biomass, not necessarily proportional to the increases in production. Increases in algal biomass are of obvious concern for the potential effects of algal decomposition on oxygen concentration. Accordingly, we chose a commonly measured indicator of algal biomass, the concentration of chlorophyll *a*, as one usable indicator of trophic state. It is only an indicator, however, not an accurate measurement. This approach is consistent with that taken in most studies of the effects of nutrient enrichment in freshwaters.

An estuary contains longitudinal gradients in chemical composition that result in gradients in natural trophic state; consequently we have selected different "standards" for chlorophyll for different parts of the Bay to reflect these gradients. We wish to emphasize that although these standards are somewhat arbitrary, they were chosen on the basis of (1) our best scientific judgment and experience, (2) standards adopted for other areas, and (3) deflection of levels from historic, natural periods of stability. As emphasized in Chapter C, early (prior to 1960's) attempts at estimating chlorophyll *a* probably erred on the high side, so the increases that have been observed since the late 1950's are probably analytically real and properly comparable. The reader is reminded here in considering our standards that a chlorophyll *a* concentration of about 100 ug l^{-1} would represent enough organic plant material alone to deplete about 12 mg l^{-1} of dissolved oxygen during decomposition (an amount of oxygen that would clearly exceed summer saturation values in the Chesapeake estuary or its tributaries).

In low-salinity areas (less than 8-12 ppt) concentrations of chlorophyll *a* between 30 and 60 ug l^{-1} during the summer months were taken to indicate moderate enrichment. Concentrations over 60 ug l^{-1} were taken to indicate high enrichment so that injury to the desired quality of the system is present or potential. In areas of higher salinity, historical data indicate that concentrations of chlorophyll *a* rarely exceeded 20 ug l^{-1} during the summer in unenriched portions of Chesapeake Bay. Therefore the observation of concentrations of 20 to 40 ug l^{-1} during the summer was taken to indicate moderate enrichment. Concentrations over 40 ug l^{-1} were taken to indicate considerable and probably undesirable enrichment. Figure E-1 shows the present (1970-1979) trophic state of Chesapeake Bay based on the summer distribution of chlorophyll *a* (from all of the data sources used in this report).

Changes in trophic state are not necessarily detrimental. Aquaculturists have been fertilizing ponds for centuries to increase production. When changes in trophic state detract from human uses, they are

BEGIN FIRST LINE OF TEXT HERE
TYPING GUIDE SHEET
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

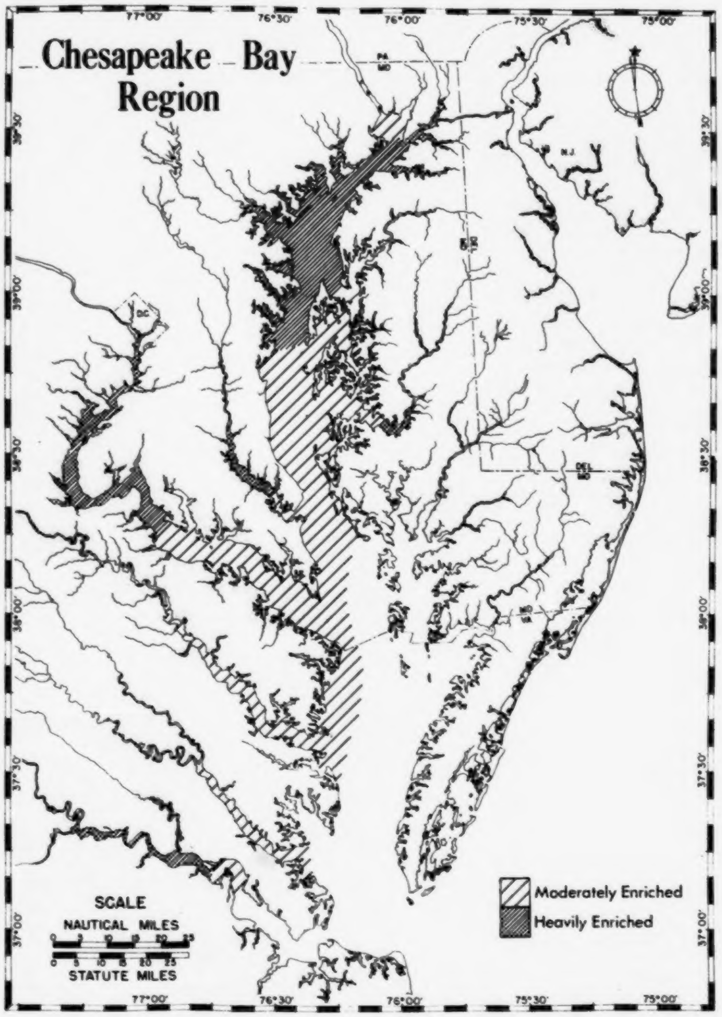

Chesapeake Bay Region
77°00'
76°30'
76°00'
75°30'
75°00'
39°30'
39°00'
38°30'
38°00'
37°30'
37°00'
DC
PA
MD
NJ
DEL
VA
SCALE
NAUTICAL MILES
0 5 10 15 20 25
0 5 10 15 20 25
STATUTE MILES
Moderately Enriched
Heavily Enriched

Figure E-1. Portions of the Chesapeake Bay that are moderately or heavily enriched.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA-287 (Cin.)
(4-76)

perceived as detrimental (see Neilson, 1980). However, one of the greatest difficulties managers face in dealing with changes in the "trophic status" of the Bay is that different users have different perceptions as to what constitutes a detrimental effect. Relative abundances of various commercial fisheries species may be altered by enrichment to the simultaneous delight and disgust of fishermen who specialize on the differently affected species.

As stated above, one clear effect of enrichment that virtually everyone preceives as detrimental is oxygen depletion in the water column. We derived a rather strong consensus from the participants at our workshop in March 1979 that alterations of natural patterns of concentrations of dissolved oxygen can provide a meaningful indication to managers of an important consequence of enrichment. We stress "alterations" because although low D.O. concentrations are certainly of ecological importance, some portions of Chesapeake Bay have naturally low concentrations of D.O. in bottom waters (Newcombe and Horne, 1938; Hires, Stroup, and Seitz, 1963) and probably are unalterable by management of anthropogenic enrichment. In contrast, Figure E-2 shows portions of Chesapeake Bay where our data review suggests that alterations of natural oxygen regimes have occurred. Detrimental effects have been noted in parts of the sub-estuaries of the mid-bay, e.g., the loss of oysters from leased grounds in the Patuxent, and obnoxious dense algal populations in the upper Potomac River. However, the picture is not yet clear for the bay proper. Deep water oxygen concentrations result from very complex interactions of respiratory and chemical processes with physical mixing processes. Oxygen measurement after a long quiescent period may reveal anoxia whereas observations following enhanced vertical mixing may show oxygen to present. The onset of seasonal oxygen decline in the spring is linked to the effect of freshwater inflow on stratification and re-oxygenation in the fall is related to the effects of surface water cooling and local wind velocity on destratification. Because these complex relationships are not completely understood and because the historical data are not accompanied by detailed local meteorological records, we must still view the apparent trends in the mid-bay cautiously.

Many of the detrimental effects of excessive enrichment are related to changes in the quality of organisms (i.e., species composition) rather than, or in addition to, changes in the quantity present. This is still another determinant of "trophic state" and "water quality." For example, blue-green algae become dominant under some circumstances, leading to other changes in the trophic structure and quality of an ecosystem. It has been suggested that "management" of trophic structure by the manipulation of nutrient balance might be possible in some cases (Ryther and Officer, 1980). Management would allow increased rates of production to be channeled into desirable products.

An increased supply of harvestable species is a worthy goal. However, our present knowledge of trophic structure and transfer rates is inadequate to permit intelligent tuning of production in estuaries. Webb (1980) has pointed out that many commonly accepted concepts about trophic relationships are really little more than dogma. Chesapeake Bay is too valuable a resource to risk further damage by allowing changes of the sort that have occurred in the upper Bay, and some tributaries, so that conservative management

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 227)
U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

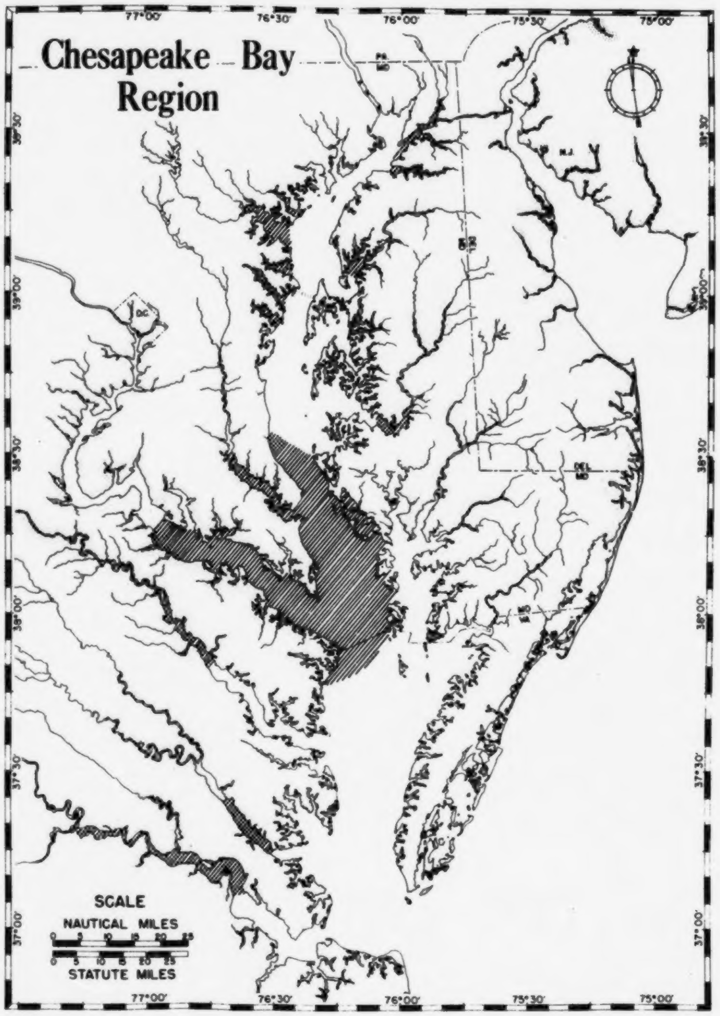

Chesapeake Bay Region
77°00'
76°30'
76°00'
75°30'
75°00'
39°30'
39°00'
38°30'
38°00'
37°30'
37°00'
SCALE
NAUTICAL MILES
0 5 10 15 20 25
STATUTE MILES
D.C.

Figure E-2. Portions of the Chesapeake Bay where natural regimes of dissolved oxygen appear to have changed (see text).

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

practices are strongly recommended.

Because not enough is presently known to "manage" properly our inputs to the Bay, sensible efforts to reduce them should continue. The indications that nitrogen, rather than phosphorus, is limiting in the lower and middle Bay suggest that affordable advanced technologies for N removal or new N input strategies should be sought. Workable management programs for the future may involve practices, such as land application, that are unconventional and have been anathema to many practicing sanitary engineers--but our minds must remain open to possible solutions to the problems, be they institutional, legal, social, or technological.

We strongly recommend continued reasoned and scientific approaches to the assessment of nutrient enrichment of estuaries. There is presently too great a desire for quick fixes to the problems and a need for better communication among managers, scientists, modelers, and the public. For their part, managers must have patience with the limitations of present scientific knowledge, be aware of the role of "basic research," and understand that indices and models do not exist that can give as output instant managerial solutions. For their part, scientists must be willing to seek practical applications of their basic research findings and to communicate and interpret scientific findings to the managers, the modelers and the public. For their part, modelers should be candid about the limitations of their models and impress upon the other parties the usefulness of models in finding gaps in knowledge and in designing future research programs to address the environmental problems. And finally, for its part the public must patiently realize that solution to enrichment problems may be costly, difficult and slow to implement, and unpopular for other reasons--but essential for future uses of the Chesapeake system.

There is no doubt in the authors' minds that Chesapeake Bay has been affected by nutrient enrichment from man's activities. Although present trends are disturbing, enrichment problems are not yet of critical proportions throughout most of the estuary, and the Bay remains for the most part an attractive and useful ecosystem. But demographic projections for the Chesapeake's watershed and our present evidence of extending alteration are portents of serious ecological losses in the future--unless preventive action is taken in the present.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 387)
U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

REFERENCES

Adams, D. D., D. T. Walsh, C. E. Grosch and C. Y. Kuo. 1975. Investigative monitoring of sewage outfalls and contiguous waters of Hampton Roads, Elizabeth and James Rivers and the lower Chesapeake Bay, Virginia, from June 1973 to May 1975. Institute of Oceanography, Old Dominion Univ., Tech. Rep. No. 22, Norfolk, Va., 206 p.

Allison, J. T. 1964. Lower Patuxent River (Chalk Point) survey data report #62-11-Px, 63-5-Px, 64-1-PX. Dept. of Water Resources, State of Md., Annapolis, Md.

Allison, J. T. 1967. The Patuxent River. Rep. No. 1 - Physical, Chemical and Bacteriological water quality. January 1961-February 1963. State of Md., Dept. of Water Res. Wat. Qual. Inves. and Anal. Div., Annapolis, Md.

Anonymous. 1968. Water quality survey of Northeast River, Elk River, C-D. Canal, Bohemia River, Sassafras River and Upper Chesapeake Bay. U.S. Dept. of Interior, Fed. Wat. Poll. Cont. Admin., Chesapeake Field Sta. Data Rep. No. 4, Annapolis, Md.

Anonymous. 1969a. Potomac River water quality, Washington, D.C. Metropolitan Area. Federal Water Pollution Control Administration, U.S. Dept. of the Interior, 80 p.

Anonymous. 1969b. The Patuxent River, water quality management technical evaluation. Federal Water Pollution Control Administration, U.S. Dept. of the Interior, Working Document No. 3, Washington, D.C.

Anonymous. 1969c. The Susquehanna River basin study, first draft, appendix J. U.S. Dept. of Agriculture, Economic Research Service, Forest Service and Soil Conservation Service, Washington, D.C.

Anonymous. 1971a. Water quality survey of the Upper Chesapeake Bay. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Data Rep. No. 24, 12 p.

Anonymous. 1971b. Upper Chesapeake Bay water quality studies: Bush River, Romney Creek, Spesutie Narrows and Swann Creek 1968-1971; Chesapeake and Delaware Canal 1970; Chester River 1970; Severn River 1970-1971; Gunpowder, Middle and Bird Rivers 1971. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Data Rep. No. 32, 27 p.

Anonymous. 1971c. Water quality survey of the head of Chesapeake Bay Maryland tributaries. U.S. Environmental Protection Agency, Annapolis

EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

Field Office, Region III, Data Rep. No. 23, 16 p.

Anonymous. 1973. 1973 Crop and Livestock Annual Summary. CRS-62 Pennsylvania Dept. of Agriculture Crop Reporting Service, 2301 North Cameron St., Harrisburg, Pa. 17120, 74 p.

Anonymous. 1974. The Patuxent River Basin Water Quality Management Plan (Draft) State of Maryland, Maryland Environmental Service.

Anonymous. 1975. Chapter IV. In: Comprehensive water quality management plan, lower Susquehanna River basin, COWAP study area 3, Gannett Fleming Corddry and Carpenter, Inc., Harrisburg, Pa. in assoc. with Kaiser Engineers, Pittsburgh, Pa.

Armstrong, F. A. J. 1951. The determination of silicate in sea water. J. Mar. Biol. Ass. U.K. 30:149-160.

Armstrong, F. A. J. 1963. Determination of nitrate in water by ultraviolet spectrophotometry. Anal. Chem. 35:1292-1294.

Astling, E. G. 1977. Daily rainfall over the Chesapeake Bay drainage basin from tropical storm Agnes. Pages 118-129 in: The effects of tropical storm Agnes on the Chesapeake Bay estuarine system. The Chesapeake Research Consortium, Inc. Pub. No. 54, The Johns Hopkins Univ. Press, Baltimore, Md.

Bain, R. C. 1967. Predicting diurnal variations in dissolved oxygen caused by algae in estuarine waters. Proc. Nat. Symp. on Estuarine Pollution, Stanford Univ., 850 p.

Barnes, H. 1959. Apparatus and methods of oceanography: Part I: Chemicals. George Allen & Unwin, Ltd., London.

Bendschneider, K. and R. J. Robinson. 1952. A new spectrophotometric method for the determination of nitrite in sea water. J. Mar. Res. 11:87-96.

Biggs, R. B. and D. A. Flemer. 1972. The flux of particulate carbon in an estuary. Mar. Biol. 12:11-17.

Boynton, W. R., W. M. Kemp and C. G. Osborne. 1980. Benthic nutrient fluxes in the sediment trap portion of the Patuxent estuary. (In press) in: V.S. Kennedy (ed.) Estuarine Perspectives, Academic Press, New York.

Boynton, W. R., E. M. Setzler, K. V. Wood, H. H. Zion, M. Homer and J. A. Mihursky. 1977. Potomac River Fisheries Program Ichthyoplankton and Juvenile Investigations, 1976, Final Report. Univ. of Maryland, Center for Environmental and Estuarine Studies, Ref. No. UMCEES 77-169 CBL, 328 p.

Bray, J. T., O. P. Bricker, and B. N. Troup. 1973. Phosphate in interstitial waters of anoxic sediments: oxidation effects during sampling procedure. Science 180:1362-1364.

BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
BEGIN LAST LINE OF TEXT
3/8"

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

TYPING GUIDE SHEET
BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Brehmer, M. L. and S. O. Haltiwanger. 1966. A biological and chemical study of the tidal James River. Virginia Institute of Marine Science. Spec. Sci. Rep. No. 6.

Brunoric, C. R. 1968. Elk River - C and D Canal physical, chemical and bacteriological water quality. State of Md., Dept. of Water Resources, Water Qual. Inves. Div. Rep. No. 1, Annapolis, Md. 25 p.

Brush, L. M., Jr. 1974. Inventory of Sewage Treatment Plants for Chesapeake Bay. Chesapeake Research Consortium, Publication No. 28, Annapolis, Md., 62 p.

Carpenter, J.H. 1965. The Chesapeake Bay Institute technique for the Winkler dissolved oxygen method. Limnol. Oceanogr. 10:141-143.

Carpenter, J. H., D. W. Pritchard and R. C. Whaley. 1969. Observations of eutrophication and nutrient cycles in some coastal plain estuaries. Pages 210-221 in: Eutrophication: causes, consequences; correctives. National Academy of Sciences, 2101 Constitution Ave., Washington, D.C. 20418, 661 p.

Chesapeake Research Consortium, Inc. 1977. The effects of tropical storm Agnes on the Chesapeake Bay estuarine system (J. Davis and B. Laird, coordinators). Chesapeake Research Consortium, Inc., Publ. 54, The Johns Hopkins Univ. Press, Baltimore, Md. 639 p.

Clark, L. J., D. K. Donnelley and O. Villa. 1973. Summary and Conclusions from the forthcoming Technical Report 56 "Nutrient Enrichment and Control Requirements in the Upper Chesapeake Bay." U.S. Environmental Protection Agency, Annapolis Field Office, Region III, EPA-9031 q-73-002-a, 24 p. plus Appendices.

Clark, L. J., V. Guide and T. H. Pheiffer. 1974. Summary and conclusions, nutrient transport and accountability in the lower Susquehanna River basin. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Tech. Rep. 60, Annapolis, Md., 91 p.

Clark, L. J. and S. E. Roesch. 1978. Assessment of 1977 water quality conditions in the Upper Potomac estuary. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, EPA 903/9-78-008, 75 p.

Correll, D. L., J. W. Pierce and M. A. Faust. 1975. A quantitative study of the nutrient, sediment, and coliform bacterial constituents of water runoff from the Rhode River watershed. Pages 131-143 in: Non-point sources of water pollution, Proc. Southeastern Regional Conference, May 1975, Blacksburg, Virginia.

Correll, D. L. 1976. The relative contribution of point and non-point sources of nutrients and pathogens. Pages 19-31 in: Water Quality Goals for Chesapeake Bay--What are they and how can they be achieved? Va. Poly. Technic. Inst. and State Univ., Blacksburg, Va. Publ. No. 706.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA-287 (Cin.)
(4-76)

Correll, D. L., T.-L. Wu, E. S. Friebele and J. Miklas. 1977. Nutrient discharge from Rhode River watersheds and their relationship to land use patterns. Pages 413-437 *in*: D. L. Correll (ed.), Watershed research in eastern North America, a workshop to compare results, vol. I, Smithsonian Institution, Chesapeake Bay Center for Environmental Studies, Edgewater, Md. 21037.

Cory, R. L. 1974. Changes in oxygen and primary production of the Patuxent estuary, Maryland, 1963 through 1969. Chesapeake Sci. 15:78-83.

Cory, R. L. and J. W. Nauman. 1970. Temperature and water quality conditions of the Patuxent River estuary, Maryland, January 1966 through December 1977. Chesapeake Sci. 11:199-209.

Cumming, H. S. 1916. Investigation of the pollution of tidal waters of Maryland and Virginia. U.S. Treasury Dept., Public Health Service, Bull. No. 75, 199 p.

Cumming, H. S., W. C. Purdy and H. P. Ritter. 1916. Investigation of the pollution and sanitary conditions of the Potomac watershed. U.S. Treasury Dept., Hygenic Laboratory Bull. No. 104, 239 p. plus plates.

Curl, H., Jr., R. Dougdale, E. Jenne, D. P. Larsen, R. Lasker, J. M. DeManche, C. Officer and J. Ryther. 1978. Ocean pollution research, development, and monitoring needs, biostimulants (Draft). Report on a Workshop at Estes Park, Colorado, July 10-14, 1978, 46 p. (unpublished).

Davis, W. D. 1973. The effect of total dissolved solids, temperature and pH on the survival of immature striped bass. The Prog. Fish-Cult. 35:157-160.

D'Elia, C. F., Webb, K. L., and Wetzel, R. L. 1980. Impact of hydrographic events on water quality in an estuary. (In press) *in*: B. J. Neilson and L. E. Cronin (eds.), Proc. of a Symposium on Nutrient Enrichment in Estuaries, Humana Press.

Deniges, G. 1920. Reaction de coloration extremement sensible des phosphates et des arseniates. C. R. Acad. Sci. 171:802-804.

Deese, P. L., R. F. Vaccaro, B. H. Ketchum, P. C. Bowker and M. R. Dennett. 1977. Ionic distribution in a spray irrigation system. Pages 39-66 *in*: Food, Fertilizer and Agricultural Residues Raymond C. Loehr (ed.), Ann Arbor Science Publishers, Inc. P.O. Box 1425, Ann Arbor, Mich. 48106.

Dow, R. L. 1977. Effects of climatic cycles on the relative abundance and availability of commerical marine and estuarine species. J. Cons. Cons. int. Explor. Mer. 37:274-280.

Durbin, A. G. and E. G. Durbin. 1975. Grazing rates of the Atlantic menhaden *Brevoortia tyrannus* as a function of particle size and concentration. Mar. Biol. 33:265-277.

Elkins, J. W. 1978. Aquatic sources and sinks for nitrous oxide. Ph.D. Thesis, Harvard Univ. Cambridge, Ma.

Elkins, J. W., S. C. Wofsy, M. B. McElroy and W. A. Kaplan. 1980. Nitrification and production of N_2O in the Potomac: evidence for variability. (In press) in: B. J. Neilson and L. E. Cronin (eds.), Proc. of a Symposium on Nutrient Enrichment in Estuaries, Humana Press.

Flemer, D. A. 1970. Primary production in the Chesapeake Bay. Chesapeake Sci. 11:117-129.

Flemer, D. A. and R. B. Biggs. 1971. Particulate carbon:nitrogen relations in northern Chesapeake Bay. J. Fish. Res. Bd. Canada 28:911-918.

Flemer, D. A., D. H. Hamilton, C. W. Keefe, and J. A. Mihursky. 1970. Final report to Office of Water Resources Research on the effects of thermal loading and water quality on estuarine primary production. Contract No. 14-01-0001-1979. Office of Water Resources Research. U.S. Dept. Interior, Washington, D.C. NRI Ref. No. 71-6, Chesapeake Biological Laboratory, Solomons, Md.

Flemer, D. A. and D. R. Heinle. 1974. Effects of waste water on estuarine ecosystems. Chesapeake Research Consortium Publ. No. 33, Annapolis, Md. 30 p.

Flemer, D. A., R. E. Ulanowicz, D. L. Taylor, Jr. 1977. Some effects of tropical storm Agenes on water quality in the Patuxent River estuary. Pages 251-287 in: The effects of tropical storm Agnes on the Chesapeake Bay estuarine system, The Chesapeake Research Consortium, Inc. Publ. No. 54, The Johns Hopkins University Press, Baltimore, Md.

Fleischer, P., T. A. Gosink, W. S. Hanna, J. C. Ludwick, D. E. Bowker and W. G. White. 1976. Correlation of chlorophyll, suspended matter, and related parameters of waters in the lower Chesapeake Bay area to LANDSAT-1 imagery. Inst. of Oceanography, Old Dominion University Tech. Rep. 28, Norfolk, Virginia, 125 p.

Garritt, D. C. and J. H. Carpenter. 1966. Comparison and evaluation of currently employed modifications of the Winkler method for determining dissolved oxygen in sea water; a NASCO report. J. Mar. Res. 24:286-318.

Glendening, M. and H. Curl, Jr. 1978. Problems of nutrient enrichment in coastal and estuarine waters (Draft). Report of a workshop held at the Pacific Marine Environmental Laboratory, Seattle, Washington, February and June 1978. 15 p. (unpublished).

Goldberg, E. D. 1979. Proceedings of a workshop on assimilative capacity of U.S. Coastal waters for pollutants. Crystal Mountain, Washington, July 29-August 4. Office of Director, NOAA, Environmental Research Laboratires, Boulder, Colorado 80393, 284 p.

Guide, V. and O. Villa. 1972. Chesapeake Bay nutrient input study. U.S.

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
TYPING GUIDE SHEET

Environmental Protection Agency, Annapolis Field Office, Region III Tech. Rep. 47.

Haas, L. W. 1977. The effect of the spring-neap tidal cycle on the vertical salinity structure of the James, York and Rappahannock Rivers, Virginia, U.S.A. Estuarine Coastal Mar. Sci. 5:485-496.

Haas, L. W., S. J. Hastings and K. L. Webb. 1980. York River Study II. Phytoplankton response to a tidally induced cycle of stratification and mixing. (In press) in: B. J. Neilson and L. E. Cronin (eds.). Proc. of a Symposium on Nutrient Enrichment in Estuaries, Humana Press.

Hargett, N. L. and J. T. Berry. 1978. 1978 fertilizer summary data. National Fertilizer Development Center, Tennessee Valley Authority, Mussel Shoals, Alabama, 132 p.

Harvey, H. W. 1934. Measurement of phytoplankton population. Mar. Biol. Ass. U.K. 19:761-773.

Harvey, H. W. 1948. The estimation of phosphate and of total phosphorus in sea waters. J. Mar. Biol. Ass. U.K. 27:337-359.

Heinle, D. R., D. A. Flemer and J. F. Ustach. 1977. Contributions of tidal marshlands to Mid-Atlantic estuarine food chains. Pages 309-320 in: M. L. Wiley, ed., Estuarine Processes, Vol. II, Academic Press, New York.

Herman, S. S., J. A. Mihursky and A. J. McErlean. 1968. Zooplankton and environmental characteristic of the Patuxent estuary. Chesapeake Sci. 9:67-82.

Hibler, W. D. and S. J. Johnson. 1979. The 20-year cycle in Greenland ice core records. Nature 280:481-483.

Hires, R. I., E. D. Stroup and R. C. Seitz. 1963. Atlas of the distribution of dissolved oxygen and pH in Chesapeake Bay, 1949-1961. Chesapeake Bay Institute, The Johns Hopkins University, Graphical Summary Rep. No. 3, 411 p.

Hyer, P. V. and E. P. Ruzecki. 1977. Changes in salinity structure of the James, York and Rappahannock estuaries resulting from the effects of tropical storm Agnes. Pages 66-80 in: The effects of tropical storm Agnes on the Chesapeake Bay estuarine system, The Chesapeake Research Consortium, Inc. Pub. No. 54, Johns Hopkins University Press, Baltimore.

Ilosvay, L. 1889. Determination of nitrite in saliva and exhaled air. Bull. Soc. Chim. Fr. 3:388-391.

Jaworski, N. A. 1980. Sources of nutrients and the scale of eutrophication problems in estuaries. (In press) in: B. J. Neilson and L. E. Cronin (eds.), Proc. of a Symposium on Nutrient Enrichment in Estuaries, Humana Press.

Jaworski, N. A., L. J. Clark and K. P. Feigner. 1971. A water resource-water supply study of the Potomac estuary. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Tech. Rep. 35.

Jaworski, N. A., L. J. Clark and K. D. Feigner. 1972. Upper Potomac estuary eutrophications control requirements. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Tech. Rep. 53, 41 p.

Jaworski, N. A., D. W. Lear, Jr. and O. Villa, Jr. 1971. Nutrient management in the Potomac estuary. U.S. Environmental Protection Agency, Middle Atlantic Region, Annapolis Field Office, Tech. Rep. 45, 64 p.

Jaworski, N. A., D. W. Lear, Jr. and O. Villa, Jr. 1972. Nutrient management in the Potomac estuary. Pages 246-273 *in*: G. E. Lickens (ed.), Nutrients and eutrophication. Amer. Soc. Limnol. Oceanogr. Spec. Symposia, vol. 1, 328 p.

Jeffries, H. P. and W. C. Johnson. 1974. Seasonal distributions of bottom fishes in the Narragansett Bay area: seven-year variations in the abundance of winter flounder (*Pseudopleuronectes americanus*). J. Fish. Res. Board Can. 31:1057-1066.

Jewel, W. S. and P. L. McCarty. 1968. Aerobic decomposition of algae and nutrient regeneration. Tech. Rep. No. 91, Dept. of Civil Engineering, Stanford Univ., Palo Alto, Ca., 283 p.

The Johns Hopkins University. 1966. The Johns Hopkins Water sciences and management program, report on the Patuxent River basin, Maryland, 228 p.

Jones, P. G. W. and C. P. Spencer. 1963. Comparison of several methods of determining inorganic phosphate in sea water. J. Mar. Biol. Ass. U.K. 43:251-273.

Jones, P. W., F. D. Martin and J. D. Hardy, Jr. 1978. Development of fishes of the mid-Atlantic bight, Vol. I Acipenseridae through Ictalvidae. U.S. Dept. of the Interior, Fish and Wildl. Serv., Wash., D.C., 366. p.

June, F. C. and F. T. Carlson. 1971. Food of young Atlantic menhaden *Brevoortia tyrannus*, in relation to metamorphosis. U.S. Fish Wildl. Serv., Fish. Bull. 68:493-512.

Kaplin, W. A., J. W. Elkins, C. E. Colb, M. B. McElroy, S. C. Wofsy and A. P. Duran. 1978. Nitrous oxide in fresh water systems: an estimate for the yield of atmospheric N_2O associated with the disposal of human waste. Pageoph. 116:423-438.

Keefe, C. W., D. A. Flemer and D. H. Hamilton. 1976. Seston distribution in the Patuxent River estuary. Chesapeake Sci. 17:56-59.

Krogh, A. 1934. A method for the determination of ammonia in water and air. Biol. Bull. 67:126-131.

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

Kuenzler, E. J., D. W. Stanley and J. P. Koenings. 1979. Nutrient kinetics of phytoplankton in the Pamlico River, North Carolina. Univ. of No. Carolina, Water Resources Research Inst., Rep. No. 139, 163 p.

Loftus, M. E., S. V. Subbs Rao and H. H. Seliger. 1975. Growth and dissipation of phytoplankton in Chesapeake Bay. I. Response to a large pulse of rainfall. Chesapeake Sci. 13:282-299.

Loftus, M. E., A. R. Place and H. H. Seliger. 1979. Inorganic carbon requirements of natural populations and laboratory cultures of some Chesapeake Bay phytoplankton. Estuaries 4:236-248.

Lund, W. A., Jr. and G. C. Maltezos. 1970. Movement and migration of bluefish, *Pomatomus saltatrix*, tagged in waters of New York and Southern New England. Trans. Am. Fish. Soc. 99:719-725.

Marks, J. W. and O. Villa, Jr. 1967. Water quality survey of the Annapolis metropolitan area. U.S. Environmental Protection Agency, Annapolis, Field Office, Region II, Data Report No. 10, 41 p.

Marks, J. W. and O. Villa, Jr. 1969. Water quality survey of the head of the Chesapeake Bay Maryland tributaries. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Data Rep. No. 12, 11 p.

McCarthy, J. J., W. R. Taylor and J. L. Taft. 1977. Nitrogenous nutrition of the plankton in the Chesapeake Bay. I. Nutrient availability and phytoplankton preferences. Limnol. Oceanogr. 22:996-1011.

McElroy, M. B., J. W. Elkins, S. C. Wofsy, C. E. Kolb, A. P. Kuran and W. A. Kaplin. 1978. Production and release of N_2O from the Potomac estuary Limnol. Oceanogr. 23:1168-1182.

McErlean, A. J. and G. J. Reed. 1979. On the application of water quality indices to the detection, measurement and assessment of nutrient enrichment in estuaries. Univ. of Md., Center for Environmental and Estuarine Studies. Ref. No. 79-138 HPEL, 145 p.

Merriman, D. 1941. Studies on the striped bass *Roccus saxatilis* of the Atlantic coast. U.S. Fish Wildl. Serv., Fish. Bull. 35, 77 p.

Merritt, D. W. 1977. Oyster spat set on natural cultch in the Maryland portion of the Chesapeake Bay (1939-1975). UMCEES Special Report No. 7, Cambridge, Md.

Mock, S. J. and W. D. Hibler. 1976. The 20-year oscillation in eastern North American temperature records. Nature 261:484-486.

Mihursky, J. A. and W. R. Boynton. 1978. Review of Patuxent estuary data base. University of Maryland, Center for Environmental and Estuarine Studies Ref. No. UMCEES 78-157-CBL.

Morris, A. W. and J. P. Riley. 1963. The determination of nitrate in sea water. Anal. Chim. Acta 29:272-279.

Mullin, J. B. and J. P. Riley. 1955. The colorimetric determination of silicate with special reference to sea and natural waters. Anal. Chim. Acta 12:162-176.

Mullin, J. B. and J. P. Riley. 1955. The spectrophotometric determination of nitrate in natural waters, with particular reference to sea water. Anal. Chim. Acta 12:464-480.

Murphy, J. and J. P. Riley. 1958. A single solution method for the determination of soluble phosphate in sea water. J. Mar. Biol. Ass. U.K. 37:9-14.

Murphy, J. and J. P. Riley. 1962. A modified single solution method for the determination of phosphate in natural waters. Anal. Chim. Acta 27:31-36.

Nash, C. B. 1947. Environmental characteristics of a river estuary. J. Mar. Res. 6:147-174.

Neilson, B. J. 1978. Final report on water quality in the Hampton Roads 208 study area. Virginia Inst. Mar. Sci., Spec. Rep. No. 171 in Applied Mar. Sci. and Ocean Eng., Gloucester Point, Va. 23062, 51 p.

Neilson, B. J. and L. E. Cronin. 1980. Proceedings of a Symposium on Effects of Nutrient Enrichment on Estuaries, Humana Press.

Newcombe, C. L. and W. A. Horne. 1938. Oxygen poor waters of the Chesapeake Bay. Science 88:80-81.

Newcombe, C. L. 1940. Studies on the phosphorus content of the estuarine waters of Chesapeake Bay. Proc. Amer. Phil. Soc. 83:621-630.

Newcombe, C. L. and H. F. Brust. 1940. Variations in phosphorus content of estuarine waters of the Chesapeake Bay near Solomons Island, Maryland. J. Mar. Res. 3:76-88.

Newcombe, C. L., W. A. Horne and B. B. Shepherd. 1939. Studies on the physics and chemistry of estuarine waters in Chesapeake Bay. J. Mar. Res. 2:87-116.

Newcombe, C. L. and A. G. Lang. 1939. The distribution of phosphates in the Chesapeake Bay. Proc. Amer. Phil. Soc. 81:393-420.

Nixon, S. W. 1980. Remineralization and nutrient cycling in coastal marine ecosystems. (In press) in: B. J. Neilson and L. E. Cronin (eds.), Proc. of a Symposium on Nutrient Enrichment in Estuaries. Humana Press.

O'Connor, D. J. 1980. Modeling of eutrophication in estuaries. (In press) in: B. J. Neilson and L. E. Cronin (eds.), Proc. of a Symposium on Nutrient Enrichment in Estuaries. Humana Press.

Olson, R. A., H. F. Brust and W. L. Tressler. 1941. Studies of the effects of industrial pollution on the lower Patapsco River area. 1. Curtis Bay Region, 1941. Chesapeake Biol. Lab. Publ. No. 43, Solomons, Md. 20688, 40 p.

Owens, W. 1969. A study of the physical hydrography of the Patuxent River and its estuary. Ches. Bay Inst. Tech. Rep. 53, Ref. 69-6. The Johns Hopkins Univ. Press, Baltimore, Md.

Patten, B. C. 1962. Dark and light bottle studies the lower Chesapeake region. Virginia Institute of Marine Science Spec. Sci. Rep. No. 39, 17 p.

Patten, B. C., R. A. Mulford and J. E. Warriner. 1963. An annual phytoplankton cycle in Chesapeake Bay. Chesapeake Sci. 4:1-20.

Pfitzenmeyer, H. T. 1962. Period of spawning and setting of the soft shelled clam, Mya arenaria, at Solomons. Chesapeake Sci. 3:114-120.

Pheiffer, T. H. 1975. Current nutrient assessment, upper Potomac estuary. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Current Assessment Paper No. 1, 22 p.

Pheiffer, T. H., D. K. Donnelly and D. A. Possehl. 1972. Water quality conditions in the Chesapeake Bay system. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Tech. Rep. 55.

Riley, J. P. 1953. The spectrophotometric determination of ammonia in natural waters with particular reference to sea water. Anal. Chim. Acta 9:575-589.

Riley, J. P. 1975. Analytical chemistry of sea water. Pages 193-514 in: J. P. Riley and G. Skirrow, eds., Chemical Oceanography, vol. 3, Academic Press, London.

Roberts, M. H., Jr., D. F. Boesch and M. E. Bender. 1975. The Chesapeake Bay: a study of present and future water quality and its ecological effects, vol. II. Analysis and projection of ecological conditions. Final Ref. to Nat. Comm. on water quality. Va. Inst. Mar. Sci. Spec. Rep. No. 91 in Applied Mar. Sci. and Ocean Eng., Gloucester Point, Va., 199 p.

Robinson, R. J. and T. G. Thompson. 1948. The determination of nitrites in sea water. J. Mar. Res. 7:42-48.

Robinson, R.J. and T. G. Thompson. 1948. The determination of silicate in sea water. J. Mar. Res. 7:49-55.

Ryther, J. H. and C. B. Officer. 1980. Impact of nutrient enrichment on water uses. (In press) in: B. J. Neilson and L. E. Cronin (eds.), Proc. of a Symposium on Nutrient Enrichment in Estuaries, Humana Press.

Salas, H. J. and R. V. Thomann. 1978. A steady-state phytoplankton model of Chesapeake Bay. J. Water Poll. Cont. Fed. 50:2752-2770.

Schubel, J. R. 1972. The physical and chemical conditions of Chesapeake Bay, an evaluation. The Johns Hopkins University, Chesapeake Bay Institute, spec. Rep. 21, 73 p, Baltimore, Md.

Schubel, J. R. and W. B. Cronin. 1977. Effects of Agnes on the distribution of dissolved oxygen along the main axis of the Bay. Pages 335-347 in: The effects of tropical storm Agnes on the Chesapeake Bay estuarine system. The Chesapeake Research Consortium, Inc. Pub. No. 54, The Johns Hopkins Univ. Press, Baltimore, Md.

Schubel, J. R., W. R. Taylor, V. E. Grant, W. B. Cronin, and M. Glendening. 1977. Effects of Agnes on the distribution of nutrients in upper Chesapeake Bay. Pages 311-319 in: The effects of tropical storm Agnes on the Chesapeake Bay estuarine system. The Chesapeake Research Consortium, Inc. Pub. No. 54, The Johns Hopkins University Univ. Press, Baltimore, Md.

Shinn, M. B. 1941. A colorimetric method for the determination of nitrite. Industr. Engng. Chem. Anal. Ed. 13:33-35.

Smayda, T. J. 1976. Plankton processes in mid-Atlantic nearshore and shelf water and energy related activities. Pages 70-95 in: B. Manowitz (ed.) Effect of energy-related activities on the Atlantic continental shelf. Proc. of a Conference at Brookhaven National Laboratory, November 10-12, 1975, Brookhaven National Laboratory 50484, 260 p.

Smith, C. L., W. G. MacIntyre, C. A. Lake, and J. G. Windsor, Jr. 1977. Effects of tropical storm Agnes on nutrient flux and distribution in lower Chesapeake Bay. Pages 299-310 in: The effects of tropical storm Agnes on the Chesapeake Bay estuarine system. The Chesapeake Research Consortium, Inc. Pub. No. 54, The Johns Hopkins Univ. Press, Baltimore, Md.

Snedaker, S., D. deSylva and D. Cottrell. 1977. A review of the role of fresh water in estuarine systems. Report to S. W. Florida Water Management District. Rosenstiel School of Marine and Atmospheric Science. 126 p.

Solorzano, L. 1969. Determination of ammonia in natural waters by the phenolhypochlorite method. Limnol. Oceanogr. 14:799-801.

Stevenson, J. C. and N. M. Confer. 1978. Summary of available information on Chesapeake Bay submerged vegetation. U.S. Department of the Interior, Fish and Wildlife Service FWS/OBS-78/66, 335 p.

Stottlemyer, J. R. 1964. Plant nutrients and primary production in the Patuxent River estuary. M.S. thesis, Univ. of Md. 1964, 41 p.

Strickland, J. D. H. 1952. The preparation and properties of silicomolybdic acid. I. The properties of alpha silicomolybdic acid. J. Am. Chem. Soc. 74:862-867.

Stross, R. G. and J. R. Stottlemyer. 1965. Primary production in the Patuxent River. Chesapeake Sci. 6:125-140.

Stroup, E. D. and J. H. Wood. 1966. Atlas of the distribution of turbidity. phosphate, and chlorophyll in Chesapeake Bay, 1949-1951. Chesapeake Bay Inst., The Johns Hopkins Univ., Graphical Summary Report No. 4, 193 p.

Sutcliffe, W. H. 1972. Some relations of land drainage, nutrient particulate matter and fish catch in two Canadian Bays. J. Fish. Res. Bd. Canada 29:357-362.

Sutcliffe, W. H. 1973. Correlation between seasonal river drainage and local landings of American lobster H. americanus and Atlantic halibut H. hipoglossus in the Gulf of the St. Lawrence. J. Fish. Res. Bd. Canada 30:856-859.

Sutcliffe, W. H., Drinkwater, K. and Muir, B. S. 1977. Correlations of fish catch and environmental factors in the Gulf of Maine. J. Fish. Res. Bd. Canada 34:19-30.

Sverdrup, H. U., M. W. Johnson and R. H. Fleming. 1942. The oceans: their physics, chemistry, and general biology. Prentice-Hall, Inc., New York, 1077 p.

Taft, J. L. and W. R. Taylor. 1976a. Phosphorus distribution in the Chesapeake Bay. Chesapeake Sci. 17:67-73.

Taft, J. L. and W. R. Taylor. 1976b. Phosphorus dynamics in some coastal plain estuaries. Pages 79-89 in: M. Wiley, ed., Estuarine Processes, Academic Press, New York.

Taft, J. L., W. R. Taylor and J. J. McCarthy. 1975. Uptake and release of phosphorus by phytoplankton in the Chesapeake Bay estuary. Mar. Biol. 33:21-32.

Taft, J. L., M. E. Loftus and W. R. Taylor. 1977. Phosphate uptake from phosphomonoesters by phytoplankton in the Chesapeake Bay. Limnol. Oceanogr. 22:1012-1021.

Taft, J. L., W. R. Taylor, E. O. Hartwig, and R. Loftus. 1980. Seasonal oxygen depletion in Chesapeake Bay. Estuaries (in press).

Taylor, W. R. and W. B. Cronin. 1974. Plankton ecology project station data, EESOP. Cruises April 1969 to April 1971. The Johns Hopkins Univ. Chesapeake Bay Institute, Spec. Rep. 38, Baltimore, Md. 228 p.

Taylor, W. R., and V. Grant. 1977. Plankton ecology project, nutrient and chlorophyll data, Aesop Cruises, April 1969 to April 1971. The Johns Hopkins Univ., Chesapeake Bay Institute, Spec. Rep. 61, Baltimore Md., 121 p.

Truitt, R. V. 1968. High winds...high tides, a chronicle of Maryland's coastal hurricanes. Univ. of Md., Natural Resources Inst. Ed. Ser. No. 77, 35 p.

Tyler, M. A., and H. H. Seliger. 1978. Annual subsurface transport of a red tide dinoflagellate to its bloom area: water circulation patterns and organism distributions in the Chesapeake Bay. Limnol. Oceanogr. 23:227-246.

Ulanowicz, R. E. 1980. An hypothesis on development of natural communities. J. theor. Biol. 85:223-245.

Ulanowicz, R. E. and B. J. Neilson. 1974. Segmentation of Chesapeake Bay: a representative exercise. Chesapeake Research Consortium Publication No. 30. Annapolis, Md., 12 p.

Ulanowicz, R. E. and D. A. Flemer. 1978. A synoptic view of a coastal plain estuary. Pages 1-26 in: J. C. J. Nihoul (ed.) Hydrodynamics of estuaries and fjords. Elsevier, Amsterdam.

Ulanowicz, R. E., W. Caplins and E. A. Dunnington. 1980. Forecasting of oyster harvests in central Chesapeake Bay. Estuarine Coastal Mar. Sci. 11:101-106.

United Nations Environment Programme. 1977. Preliminary report on the state of pollution of the Mediterranean Sea. Intergovernmental review meeting of Mediterranean coastal states on the Mediterranean action plan, Monaco, 9-14 January 1978. UNEP/IG.11/INF.4. 9 December 1977, 208 p.

United States Department of Army, Corps. of Engineers. 1973. Chesapeake Bay, existing conditions report. Appendix B, Chapter XI, 187 p.

Van Winkle, W., B. L. Kirk and B. W. Reist. 1979. Periodicities in Atlantic coast striped bass (Morone saxatilis) commerical fisheries data. J. Fish. Res. Bd. Canada 36:54-62.

Villa, O., L. J. Clark, S. E. Roesch and S. K. Smith. 1977. The Potomac estuary current assessment paper no. 2. U.S. Environmental Protection Agency, Annapolis Field Office, Region III, Current Assessment Paper No. 2, 22 p.

Virginia State Water Quality Control Board. 1976. Water quality inventory [305 (b) Report]. Information Bull. 526, Va. State Water Quality Control Bd., 361 p. plus appendices.

Vollenweider, R. A. 1969. A manual on methods for measuring primary production in aquatic environments. IBP Handbook No. 12. Blackwell, Oxford and Edinburgh, 213 p.

Wattenberg, H. 1937. Critical review of the methods used for determining

EPA Form 2360-4 (4-80)
(PREVIOUSLY EIN. EPA FORM 287)

U.S. GOVERNMENT PRINTING OFFICE: 1980-660-639

TYPING GUIDE SHEET

nutrient salts and related constituents in salt water. I. Methoden zur Bestimmung von Phosphat, Silikat, Nitrat und Ammoniak im See wasser. Conseil Permanent International Pour L'Exploration De La Mer. Rapports et Proces-Verbaux des Reunions Vol. CIII, Part 1, pp. 1-26. (D'Elia has translation by N. W. Rakestraw at CBL).

Webb, K. L. 1980. Conceptual models and processes of nutrient cycling in estuaries. (In press) in: B. J. Neilson and L. E. Cronin (eds.) Proc. of a Symposium on Nutrient Enrichment in Estuaries, Humana Press.

Webb, K. L. and C. F. D'Elia. 1980. Nutrient and oxygen redistribution during a spring-neap tidal cycle in a temperate estuary. Science 207:983-985.

Whaley, R. C., J. H. Carpenter and R. L. Baker. 1966. Nutrient data summary 1964, 1965, 1966: Upper Chesapeake Bay (Smith Point to Turkey Point) Potomac, South, Severn, Magothy, Back, Chester, and Miles Rivers; and Eastern Bay. The Johns Hopkins Univ., Chesapeake Bay Institute, Spec. Rep. 12, Baltimore, Md. 88 p.

Winkler, L. W. 1888. Die Bestimmung des im Wasser gelosten Sauerstoffen. Ber Dtsche. Chem. Ges. 21:2843-2855.

Wolman, M. G. 1971. The nation's rivers. Science 174:905-918.

Wolman, A. and J. Geyer. 1957. A clean Potomac River in the Washington metropolitan area. Interstate Commission on the Potomac River Basin, October 1957, 63 p.

Wood, E. D., F. A. J. Armstrong and F. A. Richards. 1967. Determination of nitrate in sea water by cadmium-copper reduction to nitrite. J. Mar. Biol. Ass. U.K. 47:23-31.

Wooster, W. S. and N. W. Rakestraw. 1951. The estimation of dissolved phosphate in sea water. J. Mar. Res. 10:91-100.

Yentsch, C. S. and D. W. Menzch. 1963. A method for the determination of phytoplankton chlorophyll and phaeophytin by fluorescence. Deep-Sea Res. 10:221-231.

Zubkoff, P. L. and J. E. Warriner. 1975. Synoptic sightings of red waters of the lower Chesapeake Bay and its tributary rivers. Pages 105-111 in: V. R. Lo Crierro (ed.) Proc. First Int. Conf. on Toxic Dinoflagellate Blooms. Mass. Sci. and Tech. Found., Wakefield, Mass.

Zubkoff, P. L. and J. E. Warinner, III. 1977. The effects of tropical storm Agnes as reflected in chlorophyll a and heterotrophic potential of the lower Chesapeake Bay. Pages 368-388 in The effects of tropical storm Agnes on the Chesapeake Bay estuarine system. The Chesapeake Research Consortium, Inc. Pub. No. 54, The Johns Hopkins Univ. Press, Baltimore, Md.

Appendix A

Accessing Environmental Data Base
Directory Climatic Data

J. S. Wilson

EPA Form 2350-4 (4-80)
(PREVIOUSLY F/N: EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE 1980-660-638
TYPING GUIDE SHEET

Appendix A

Computer System

Access to the University of Maryland computer facilities used to store the data and programs described herein require both an account number and password. Interested persons may request the creation of a computer account through the Office of User Services, Computer Science Center, University of Maryland, College Park, MD, 20742 (301) 454-4255. Applicants need request access to the UNIVAC 1108 only since no project data is immediately accessable via the companion computer system (UNIVAC 1100/41).

Since instruction in the operating system command language is beyond the scope of this report, no detailed explanations of the computer commands recommended for use in accessing project data will be given. An assumption of working familiarity with the UNIVAC command language is made. Documentation of the operating system command syntax and usage is found in a Computer Science Center computer note CN-13.3 [1]. Computer notes are available for reference or sale at the program library, Computer Science Center, (301) 454-4261.

Accessing Climatic Data

The 26 annual series of environmental data referenced in Chapter D of this report are stored as individual elements (named A-Z) of a program file on a reel of magnetic tape (reel number P10934) at the Computer Science Center of the University of Maryland. The program file is the first file on tape P10934 and was copied using @COPY with the "G" option at a density of 6250 frames per inch.

The individual annual series are described below with their corresponding element names.

A	Annual Average Salinity
B	Annual Average Water Temperature
C	Annual Average Air Temperature
D	Annual Average Precipitation
E	Annual Cumulative Excesses Salinity
F	Annual Cumulative Excesses Water Temperature
G	Annual Cumulative Excesses Air Temperature
H	Annual Cumulative Excesses Precipitation
I	Annual Cumulative Deficits Salinity

---

[1] University of Maryland UNIVAC 1100 Series Re Publication CN-13.3 Prochazka, J.C. and E.U. Putnam, Computer Science Center, University of Maryland, January 1976

J	Annual Cumulative Deficits Water Temperature
K	Annual Cumulative Deficits Air Temperature
L	Annual Extreme Values Salinity +
M	Annual Extreme Values Salinity -
N	Annual Extreme Values Water Temperature +
O	Annual Extreme Values Water Temperature -
P	Annual Extreme Values Air Temperature +
Q	Annual Extreme Values Air Temperature -
R	Annual Extreme Values Precipitation +
S	Annual Episodes Salinity +
T	Annual Episodes Salinity -
U	Annual Episodes Water Temperature +
V	Annual Episodes Water Temperature -
W	Annual Episodes Air Temperature +
X	Annual Episodes Air Temperature -
Y	Annual Episodes Precipitation +
Z	Annual Episodes Precipitation -

The following operating system commands will create a mass storage file and copy the climate data into that file.

```
@CAT,P CLIMATE.
@ASG,T TAPE.,U9S,P10934
@COPY,G TAPE.,CLIMATE.
```

If no other data from the tape is required, it may be released by the following commands.

```
@REWIND TAPE.
@FREE TAPE.
```

The Univeristy of Maryland Text Editor processor <@ED> may then be used to examine and extract individual elements of the mass storage file CLIMATE. which now contain the climatic data. The Text Editor is documented in Univeristy of Maryland Computer Note CN-7.9 [1] (or latest version). This manual is also available from the Computer Science Center's program library.

---

[1] Text Editor User's Guide, Computer Note CN-7.9, ,P.E. Hagerty and K.E. Sibbald, Computer Science Center, Univeristy of Maryland, August 1976

EPA Form 2350-4 (4-80)

TYPING GUIDE SHEET

Appendix B

Environmental Data Base Directory

M. Cole-Jones

A. B. Caplins

J. S. Wilson

D. R. Heinle

Table of Contents

Preface 133

Listing of data files by number 134

Key to file descriptors 135

Parameter code 137

Abbreviated description of data files 139

Data Base description 142

Instructions for use of Data Base 212

Preface

The beginning point for the following data base was the compilation from the NODC system by Lynch and McErlean (EPA Contract #68-01-3994 to the Chesapeake Research Consortium, Inc.). It was apparent that the Bay Data Directory produced by that contract did not include reference to a number of older studies and some fairly large recent sets of data. The following data base directory is meant, in part, to supplement the work that preceded it. It is designed to include all of the information necessary for direct incorporation into the EDBD data directory. Lines beginning with "1" on page 2 identify that information. Since we have also acquired actual data, in contrast to EDBD or the compilation by Lynch and McErlean who only identified data bases, fields describing the actual data content were necessary. Lines beginning with "5" on pages 2 and 3 identify the major categories of information in the data base.

There are a number of automated data bases which have not been acquired by this project because of insufficient time, funds, or legal restraints. Those that we know of are: State of Maryland; U.S. Geological Survey; Smithsonian Institution; and the Phildalphia Academy of Natural Sciences.

Some of these data should be available upon the completion of litigation concerning power plant operations (Section 315, PL 92-500).

```
                    ****** DATAFILES ******
GROUPID DATAFILES
GROUPID EDBD
GROUPID PCODE
GROUPID DESCRIP
GROUPID M000295
GROUPID M020001
GROUPID M020002
GROUPID M022001
GROUPID M022002
GROUPID M022003
GROUPID M022004
GROUPID M022005
GROUPID M022006
GROUPID M022007
GROUPID M022008
GROUPID M022009
GROUPID M022010
GROUPID M022011
GROUPID M022012
GROUPID M022013
GROUPID M022014
GROUPID M022015
GROUPID M022016
GROUPID M022017
GROUPID M022018
GROUPID M022019
GROUPID M022020
GROUPID M022021
GROUPID M022022
GROUPID M022023
GROUPID M022024
GROUPID M022025
GROUPID M022026
GROUPID M022027
GROUPID M022028
GROUPID M022029
GROUPID M022030
GROUPID M022031
GROUPID M022032
GROUPID M022033
GROUPID M022034
GROUPID M022035
GROUPID M022036
GROUPID M022037
GROUPID M022038
GROUPID M022039
GROUPID M022040
GROUPID M022041
GROUPID M022042
GROUPID M022043
GROUPID M022044
```

```
                     ******  EDED ******
THE RECORD DESIGNATION AND NAME/DESCRIPTION FOR THE EUTROPHICATION PROJECT
DATA DIRECTORY REFERENCE FILE (DDRF) FORMAT E-1.

1  2 <ASSESSION NUMBER>
         MODIFIED BY PREFIXING AN "M" OR A "V" TO THE 6 DIGIT NUMERICAL FIELD
1  4 <INSTITUION> /A THESAURUS CONTROLLED FIELD/
1  7 <FILE NAME>
1 10 <PROJECT> /A THESAURUS CONTROLLED FIELD/
1 14 <GENERAL GEOGRAPHIC AREA>
1 17 <REMARKS>
1 18 <NAME>
         TO CONTACT FOR ACCESS TO DATA SE.
1 19 <PHONE NUMBER>
1 20 <INSTITUTION OR AGENCY>
1 21 <STREET>
1 22 <CITY>
1 23 <STATE>
1 24 <COUNTRY>
1 25 <ZIP CODE>
1 27 <FILE SIZE>
**ALL RECORD TYPES AND DESCRIPTIONS BELOW ARE "LOCAL" TO THE E-1 FORMAT**
**PARAMETER GROUPS, DESIGNATIONS AND NUMBER OF DATA POINTS PER PARAMETER GROUP**
         5 35 THROUGHT 5 52  ENTER NAME THE SPECIFIC PARAMETER STARTING AT COL 6
         TAB TO COL 25 AND RIGHT JUSTIFY THE NUMBER OF DATA POINTS / PARAM.
5 35 PLANT PIGMENTS
5 36 ALGAL STANDING CROP
5 37 TURBIDITY
5 38 DO
5 39 PHOSPHOROUS
5 40 NITROGREN
5 41 SILICON
5 42 ORGANIC CARBON
5 43 SUSPENDED SOLIDS
5 44 COLIFORMS
5 45 TEMPERATURE
5 46 SALINITY
5 47 ALKALINITY
5 48 PH
5 49 BOD
5 50 BIOLOGICAL ACTIVITY
5 51 CHEMICAL LOSS ON IGNITION
5 52 LOSS ON IGNITION
         5 53 - 5 55 ARE "OTHER" FOR USE IN REPORTING "OTHER" PARAMTERS
5 53 OTHER
5 54 OTHER
5 55 OTHER
5 56 TOTAL NUMBER OF SAMPLES
         OPTIONAL IF NUMBER OF DATA POINTS WERE ENTERED FOR THE PARAMETERS ABOVE
**LOCATION
5 57 STATION NAME
5 58 GRID LOCATOR (COL 6-19), LATITUDE (COL 21-26) LONGITUDE (COL 28-34)
         THE ABOVE PAIR OF RECORD TYPES ARE REPEATED FOR EACH LOCATION IN
         THE DATA SET.
**SAMPLING DATES
```

```
5 59 BEGIN (MMDDYY) (COL 6-11), END (MMDDYY) (COL 13-18),
5 59 SAMPLING FREQUENCY (N) (COL 20-22) PER (PERIOD) (COL 24)
5 59 NUMBER OF STATIONS (COL 26-28)
**DATA SET EVALUATION
5 60 INITIAL REVIEW BY (NAME) (COL 6-23)
5 60 ACCEPTABLE (COL 25), UNACCEPTABLE (COL 26)
         IF UNACCEPTABLE , ENTER THE REASON ON AS MANY (OR AS FEW) RECORD
         TYPE 5 61 RECORDS AS REQUIRED
5 61 UNACCEPTABLE (COL 6-80)
5 62 FINAL REVIEW BY (NAME) (COL 6-23), ACCEPTABLE (COL 24)
5 62 UNACCEPTABLE (COL 25)
         AS ABOVE USE 5 63 RECORDS TO DOCUMENT REJECTION REASON
5 63 UNACCEPTABLE (COL 6-80)
**SOURCE MEDIA
5 64 NON MACHINE READABLE SOURCE  FIELD NOTEBOOKS (COL 6),
5 64 DATA SHEETS (COL 7), REP (COL 8), PHOTOGRAPHS (COL 9),
5 64 ANALOG FORMS (COL 10)
5 64 MACHINE READABLE SOURCE  CARDS (COL 12), TAPE (COL 13),
5 64 IF ON TAPE, WHAT KINGD OF HOST SYSTEM (COL 15-80)
```

```
                     ****** PCODE ******
00005 SAMPLING STATION LOCATION, VERTICAL, PERCENT OF TOTAL DEPTH (FEET)
00010 TEMPERATURE, WATER (DEGREES CENTIGRADE)
00020 TEMPERATURE, AIR (DEGREES CENTIGRADE)
00031 LIGHT, INCIDENT, % REMAINING AT CERTAIN DEPTH
00060 FLOW, STREAM, MEAN DAILY (CUBIC FEET PER SEC.)
00061 FLOW, STREAM, INSTANTANEOUS (CUBIC FEET PER SEC.)
00070 TURBIDITY, ( JACKSON CANDLE UNITS )
00074 TURBIDITY, TRANSMISSIOMETER, % TRANSMISSION
00075 TURBIDITY, HELLIGE (PPM AS SILICON DIOXIDE)
00076 TURBIDITY, HACH TURBIDIMETER ( FORMAZIN TURB UNIT )
00077 TRANSPARENCY, SECCHI DISC (INCHES)
00078 TRANSPARENCY, SECCHI DISC (METERS)
00095 CONDUCTIVITY AT 25 DEGREES C (MIRCOMHOS)
00096 SALINITY AT 25 DEGREES C (MG/ML)
00295 OXYGEN, DISSOLVED (ML/L)
00299 OXYGEN, DISSOLVED, ( ELECTRODE ) ( MG/L )
00300 OXYGEN, DISSOLVED (MG/L)
00301 OXYGEN, DISSOLVED (PERCENT OF SATURATION)
00310 BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
00400 PH (STANDARD UNITS)
00410 ALKALINITY, TOTAL (MG/L AS CACO3)
00415 ALKALINITY, PHENOLPHTALEIN (MG/L AS CACO3)
00425 ALKALINITY, BICARBONATE (MG/L AS CACO3)
00430 ALKALINITY, CARBONATE (MG/L AS CACO3)
00440 BICARBONATE ION (MG/L AS HCO3)
00445 CARBONATE ION (MG/L AS CO3)
00480 SALINITY - PARTS PER THOUSAND
00500 RESIDUE (SOLIDS) TOTAL (MG/L)
00505 RESIDUE, TOTAL, VOLATILE (MG/L)
00510 RESIDUE, TOTAL FIXED (MG/L)
00530 RESIDUE, TOTAL, NON FILTERABLE (MG/L)
00600 NITROGEN, TOTAL (MG/L AS N)
00602 NITROGEN, DISSOLVED (MG/L AS N)
00607 NITROGEN, ORGANIC, DISSOLVED (MG/L AS N)
00608 NITROGEN, AMMONIA, DISSOLVED (MG/L AS N)
00610 NITROGEN, AMMONIA, TOTAL  (MG/L AS N)
00613 NITRITE NITROGEN, DISSOLVED (MG/L AS N)
00615 NITRITE NITROGEN, TOTAL (MG/L AS N)
00618 NITRATE NITROGEN, DISSOLVED (MG/L AS N)
00620 NITRATE NITROGEN, TOTAL (MG/L AS N)
00623 NITROGEN, KJELDAHL, DISSOLVED (MG/L AS N)
00625 NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
00629 NITROGEN, ORGANIC, KJELDAHL, TOTAL, (MG/L AS N)
00630 NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
00631 NITRITE PLUS NITRATE, DISS. 1 DET. (MG/L AS N)
00650 PHOSPHATE, TOTAL (MG/L AS PO4)
00653 PHOSPHATE, TOTAL SOLUBLE (MG/L)
00660 PHOSPHATE, ORTHO (MG/L AS PO4)
00665 PHOSPHORUS, TOTAL (MG/L AS P)
00666 PHOSPHORUS, DISSOLVED (MG/L AS P)
00669 PHOSPHORUS, TOTAL HYDROLYZABLE (MG/L AS P)
00671 PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
00672 PHOSPHORUS, DISSOLVED HYDROLYZABLE (MG/L AS P)
```

00673	PHOSPHORUS, DISSOLVED ORGANIC (MG/L AS P)
00680	CARBON, TOTAL, ORGANIC (MG/L AS C)
00681	CARBON, DISSOLVED ORGANIC (MG/L AS C)
00690	CARBON, TOTAL (MG/L AS C)
00940	CHLORIDE (MG/L AS CL)
00946	SULFATE, DISSOLVED (MG/L AS SO4)
00955	SILICA, DISSOLVED (MG/L AS SIO2)
00956	SILICA, TOTAL (MG/L AS SIO2)
31501	COLIFORM, TOTAL, MEMBRANE FILTER IMMED. M-ENDO MED 35C (#/100ML)
31505	COLIFORM, TOTAL, MPN, CONFIRMED TEST, 35 C (TUBE 31506)
31506	COLIFORM,TOTAL,MPN,CONFIRMED TEST,TUBE CONFIG. (MPN/100ML)
31614	FECAL COLIFORM, MPN, TUBE CONFIGURATION
31615	FECAL COLIFORM, MPN, EC MED, 44.5C,(TUBE31614)(MPN/100ML)
31616	FECAL COLIFORM, MEMB. FILTER, M-FC BROTH 44.5 C (#/100ML)
31677	FECAL STREPTOCOCCI, MPN, AD-EVA, 35 C (MPN/100ML)
31751	PLATE COUNT, TOTAL, TPC AGAR 35 C/24HR (#/1 ML)
32209	CHLOROPHYLL A UG/L FLUOROMETRIC CORRECTED
32210	CHLOROPHYLL-A, TRICHROMATIC UNCORRECTED (UG/L)
32211	CHLOROPHYLL A (UG/L) SPECTROPHOTOMETRIC METHOD
32212	CHLOROPHYLL B, TRICHROMATIC, UNCORRECTED (UG/L)
32214	CHLOROPHYLL C, TRICHROMATIC, UNCORRECTED (UG/L)
32216	CHLOROPHYLL, TOTAL, TRICHROMATIC UNCORRECTED (UG/L)
32221	CHLOROPHYLL-A, % OF (PHEOPHYTON-A + CHLOROPHYLL-A),SPEC-ACID
32230	CHLORPHYL A (MG/L)
32235	CHLOROPHYLL, TOTAL (SARGENT METHOD-667MU) UG/L
50060	CHLORINE, TOTAL RESIDUAL (MG/L)
70205	TIDE, RANGE (FEET) BETWEEN ADJACENT HIGH - LOW TIDES
70505	PHOSPHATE, TOTAL, COLORIMETRIC METHOD (MG/L AS P)
70507	PHOSPHORUS, IN TOTAL ORTHOPHOSPHATE (MG/L AS P)
71100	SEDIMENT, SUSPENDED PARTICULATE (MG/L)
71845	NITROGEN, AMMONIA, TOTAL (MG/L AS NH4)
71851	NITRATE NITROGEN, DISSOLVED (MG/L AS NO3)
71886	PHOSPHORUS, TOTAL, AS PO4 - MG/L
71888	PHOSPHORUS, TOTAL, SOLUABLE AS PO4 (MG/L)
74010	IRON, TOTAL (MG/L AS FE)
98753	ALKALINITY, METHYL PURPLE (MG/L AS CACO3)
98754	TURBIDITY, PHOTOMETRIC 420 MU (MG/L)
98755	PHOSPHORUS, PARTICULATE UNREACTIVE (UG AT/L)
98756	PHOSPHORUS, PARTICULATE REACTIVE (UG AT/L)
98757	LOSS ON IGNITION (OF SUSPENDED SEDIMENT) (MG/L)
98758	NITROGEN, PARTICULATE, ORGANIC (UG AT /L)
98759	PLATE COUNT, TOTAL, BACTERIA, TPC AGAR, 20 DEG C, 36 HRS
98760	COLIFORM, TOTAL, MPN, TUBE CONFIGURATION
98761	CHEMICAL OXYGEN DEMAND, DISSOLVED, KMNO4, (MG O2 CONSUMED / L)
98762	CONDUCTIVITY AT AMBIENT TEMP (MICROMHOS)
98763	CARBOHYDRATE, PARTICULATE (MG/L AS SUCROSE) <NSC>
98764	NITROGEN, PARTICULATE (MG-AT/L AS N) <NSC>
98765	CARBON, PARTICULATE ORGANIC (?) <NSC>

```
****** DESCRIP ******
M020001
1  7 1972 PATUXENT RIVER SYNOPTIC PHYSICAL/CHEMICAL DATA SET
1 10 A SYNOPTIC VIEW OF A COASTAL PLAIN ESTUARY
M020002
1  7 UPPER POTOMAC RIVER WATER QUALITY DATA
1 10 [PROJECT]
M022001
1  7 MIHURSKY, MCERLEAN, HERMAN  1967 NRI REF 67-59
1 10 COOPERATIVE ZOOPLANKTON INVESTIGATIONS IN THE PATUXENT RIVER
1 10 ESTUARY DURING THE PERIOD JULY 1963 - FEBRUARY 1965
M022002
1  7 PATUXENT RIVER 1967 THRU 1970 WATER QUAL - EPA
1 10 1967 THRU 1970 WATER QUALITY SURVEY OF PATUXENT RIVER
1 10 DATA REPORTS #15, #16, #17, #34
M022003
1  7 D. A. FLEMER ETAL, NRI REF 71-6, 71-6B
1 10 EFFECTS OF THERMAL LOADING AND WATER QUALITY ON ESTUARINE PRIMARY
1 10 PRODUCTIVITY OF THE PATUXENT RIVER 1968 - 1971
M022004
1  7 EARLY CHES BIOL LAB PIER DATA 1938-43
M022005
1  7 EARLY CHES BIOL LAB CRUISE DATA 1936 - 1939
M022006
1  7 WATER QUALITY SURVEY OF THE UPPER CHESAPEAKE BAY 1969 -1970 -1971
1  7 DATA REPORT # 24.
M022007
1  7 CHESAPEAKE BAY NUTRIENT INPUT STUDY
1  7 EPA TECHNICAL REPORT #47 SEPT 1972
M022008
1  7 COOPERATIVE BACTERIOLOGICAL STUDY UPPER CHESAPEAKE BAY DREDGING
1  7 SPOIL DISPOSAL  CRUISE REPORT #1 1967
M022009
1  7 BOHEMIA RIVER, SASSAFRAS RIVER AND UPPER CHESAPEAKE BAY, SUMMER 1968.
1 10 WATER QUALITY SURVEY OF THE HEAD OF THE CHES BAY
1 10 MARYLAND TRIBUTARIES DATA REPORT #12 (1969)
1 10 AND DATA REPORT # 23 (1970-71)
M022010
1  7 POLLUTION SURVEY OF THE PATAPSCO RIVER, BALTIMORE HARBOR
1  7 1938-1939  ROBERT A   . LITTLEFORD
M022011
1  7 ELK RIVER - C&D CANAL; PHYSICAL, CHEMICAL, AND BACTERIOLOGICAL
1  7 WATER QUALITY REPORT #1   OCT 1967 - JULY 1968
M022012
1  7 COLIFORM AND E. COLI BACTERIA COUNTS AT A MAJOR CHESAPEAKE BAY
1  7 BOATING - BATHING SITE DURING THE INDEPENDENCE DAY HOLIDAY PERIOD,1964
M022013
1  7 WATER QUALITY FROM SELECTED STATIONS IN CHESAPEAKE BAY AND THE
1  7 POTOMAC RIVER 1967
M022014
1  7 FISH KILL INVESTIGATIONS ST MICHAELS HARBOR, OAK CREEK, MILES RIVER ESTUARY
1  7 PHYSICAL, CHEMICAL AND BACTERIOLOGICAL WATER QUALITY,
1  7 SUMMER 1969 TO OCTOBER 1970
M022015
1  7 BIOL SURVEY OF THE UPPER POTOMAC RIVER AND SELECTED TRIBS 1966-68
```

```
1  7 DATA REPORT #4
M022016
1  7 UPPER POTOMAC ESTUARY EUTROPHICATION CONTROL REQUIREMENTS
1  7 TECHNICAL REPORT #53  APRIL 1972
M022017
1  7 PHOSPHATE DETERMINATIONS - CHESAPEAKE SHELLFISH INVESTIGATIONS
1  7 1952  JIM ENGLE
1 10 MARYLAND OYSTER BAR SURVEYS
M022018
1  7 A BIOLOGICAL AND CHEMICAL STUDY OF THE TIDAL JAMES RIVER.
1  7 1966 VIMS REPORT BY M.L. BREHMER & S.O. HALTIWANGER
M022019
1  7 LITTLE COVE POINT BAY OXYGEN PROGRAM 1958-1965
M022020
1  7 POTOMAC RIVER (MORGANTOWN) RIVER SURVEY REPORTS 1966,1968,1972,1973
1  7 CHEMICAL, BACTERIOLOIGCAL AND PHYSICAL WATER QUALITY STUDIES
1  7 1969 THRU 1974
1 10 POTOMAC RIVER SURVEY
M022021
1  7 A CHEMICAL, BACTERIOLOGICAL AND PHYSICAL STUDY ON THE CHESAPEAKE
1  7 BAY IN THE VICINITY OF CALVERT CLIFFS 1968,69,70,71,72,73,75
1  7 FOR BALTIMORE GAS & ELECTRIC (BG&E)
1 10 CALVERT CLIFFS BASELINE STUDY FOR BG&E
M022022
1  7 CHESAPEAKE BAY SURVEYS (CALVERT CLIFFS) SURVEY REPORT
1  7 FOR BALTIMORE GAS & ELECTRIC (BG&E) 1968 THRU 1975
1 10 CALVERT CLIFFS BASELINE STUDY
M022023
1  7 WATER QUALITY SURVEY OF THE CHESAPEAKE BAY IN THE VICINITY OF
1  7 SANDY POINT DATA REPORTS #13 (1968), #14 (1969), #22 (1970)
M022024
1  7 WATER QUALITY SURVEY OF THE POTOMAC ESTUARY 1967 DATA REPORT
M022025
1  7 WATER QUALITY SURVEY OF THE POTOMAC ESTUARY TRANSPORT SURVEY
1  7 1969-70  DATA REPORT #20
M022026
1  7 INVESTIGATIONS OF THE POLLUTION OF TIDAL WATERS OF MARYLAND AND VIRGINIA
1  7 (WITH SPECIAL REFERENCE TO SHELLFISH BEARING AREAS) PUBLIC HEALTH
1  7 BULLETIN #74 MARCH 1916  HUGH S. CUMMINGS
M022027
1  7 MORGANTOWN STATION AND THE POTOMAC ESTUARY: A 316 ENVIRONMENTAL
1  7 DEMONSTRATION FOR PEPCO VOL I,II,III  SUMMARY   SEPT 1977
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
M022028
1  7 PRIMARY PRODUCTIVITY STUDIES IN THE LOWER POTOMAC RIVER NEAR
1  7 MORGANTOWN SES FOR PEPCO JULY 1974 (DATA 9-71 TO 6-73)
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
M022029
1  7 PRODUCTIVITY STUDIES ON THE POTOMAC RIVER 1967-1970, 1971-1973
1  7 (PUBL OCT 1972 & JULY 1974 RESPCTIVELY)
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
M022030
1  7 AN ANNUAL PLANKTON CYCLE ON THE POTOMAC RIVER IN THE VICINITY OF
1  7 MORGANTOWN S.E.S. JUNE 1969 TO MAY 1970 TO PEPCO MARCH 1972
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
```

```
M022031
1  7 1976,1977 (2 REPORTS) BIOLOGICAL STUDIES ON THE POTOMAC RIVER
1  7 NEAR THE MORGANTOWN SES FOR PEPCO (PUBL 1978,79)
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
M022032
1  7 POTOMAC RIVER 1977 ZOOPLANKTON SURVEY
1 10 POWER PLANT SITING PROGRAM (PPSP)
M022033
1  7 1978 PATUXENT RIVER SURVEY
1 10 POWER PLANT SITING PROGRAM (PPSP)
M022034
1  7 WATER QUALITY OF THE POTOMAC ESTUARY GILBERT SWAMP AND ALLENS
1  7 FRESH AND GUNSTON COVE  DATA REPORT #30   1970
M022035
1  7 UPPER CHESAPEAKE BAY WATER QUALITY STUDIES : BUSH RIVER,  ROMNEY CREEK,
1  7 SPESUTIE NARROWS, SWAN CREEK 1968-71; C&D CANAL, CHESTER RIVER 1970;
1  7 SEVERN RIVER 1970-71; GUNPOWDER, MIDDLE, BIRD RIVERS 1971
1  7 DATA REPORT #32
M022036
1  7 WATER QUALITY SURVEY OF THE ANNAPOLIS METROPOLITAN AREA
1  7 DATA REPORT #10  1967
M022037
1  7 SPECIAL WATER QUALITY SURVEYS OF THE POTOMAC RIVER BASIN
1  7 ANACOSTIA ESTUARY 1970; WICOMICO RIVER AND ST. CLEMONT
1  7 AND BRETON BAYS 1971; OCCOQUAN BAY 1971  DATA REPORT #33
M022038
1  7 WATER QUALITY SURVEY OF THE UPPER POTOMAC ESTUARY
1  7 ENFORCEMENT CONFERENCE AREA  DATA REPORT #29 1970
M022039
1  7 SURVEY RESULTS OF CHESAPEAKE BAY INPUT STUDY 1969-70
1  7 DATA REPORT #31
M022040
1  7 POTOMAC ESTUARY WASTEWATER TREATMENT PLANTS
1  7 SURVEY  DATA REPORT #27 1970
M022041
1  7 NUTRIENT DATA ON SEDIMENT SAMPLES OF THE PATUXENT ESTUARY
1  7 1966-68  DATA REPORT #11
M022042
1  7 CONSOLIDATED WATER QUALITY SURVEY OF THE POTOMAC ESTUARY
1  7 DATA REPORT #25 1970
M022043
1  7 WATER QUALITY SURVEY OF THE POTOMAC ESTUARY EMBAYMENTS AND TRANSECTS
1  7 DATA REPORT #28 1970
M022044
1  7 INVESTIGATIONS OF THE POLLUTION AND SANITARY CONDITIONS OF THE
1  7 POTOMAC WATERSHED WITH SPECIAL REFERENCE TO SELF PURIFICATION AND
1  7 SANITARY CONDITIONS OF SHELLFISH IN THE LOWER POTOMAC RIVER.
1  7 HYGENIC LABORATORY #104 FEBRUARY 1916 HUGH S. CUMMINGS
M000295
1  7 BIOLOGICAL AND GEOLOGICAL RESEARCH ON THE EFFECTS OF
1  7 DREDGING SPOIL DISPOSAL IN THE UPPER CHESAPEAKE BAY
1 10 SPOIL DISPOSAL IN THE UPPER CHESAPEAKE BAY
```

```
****** M000295 ******
1  2 M000295
1  4 C BIO LAB
1  7 BIOLOGICAL AND GEOLOGICAL RESEARCH ON THE EFFECTS OF DREDGING
1  7 AND SPOIL DISPOSAL IN UPPER CHESAPEAKE BAY
1 10 SPOIL DISPOSAL IN UPPER CHESAPEAKE BAY
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY
1 17 WATER QUALITY DATA ONLY ENCODED FROM SELECTED AND MID-CHANNEL
1 17 STATIONS. REPORT ALSO INCLUDES DATA FROM 5 BAY TRANSECTS WITH 4-6
1 17 STATIONS EACH; THIS DATA NOT ENCODED
1 18 LIBRARIAN
1 19 301-326-4281
1 20 CHESAPEAKE BIOLOGICAL LAB
1 21 BOX 38
1 22 SOLOMONS
1 23 MARYLAND
1 25 20688
5 35 1 CHL A
5 42 1 PARTIC ORG
5 43 1 SESTON
5 45 1
5 46 1
5 53 1 SECCHI
5 57 SUS
5 58 73079630243363 393236760433
5 57 IC
5 57 73079620615139 392653760119
5 57 IIC
5 57 73079620364113 392341760613
5 57 SAS
5 57 73079620213561 392236760151
5 57 IIIC
5 58 73079621005251 392055761021
5 57 IVC
5 58 73079611645330 391653761430
5 57 VC
5 58 73079611465254 391455761624
5 57 VI
5 58 73079602915128 390952762118
5 57 PLANKTON STATION 1
5 58 73078622000000 382000762000
5 57 PLANKTON STATION 2
5 58 73078632243000 383230762400
5 57 PLANKTON STATION 3
5 58 73078642550000 384500762500
5 57 PLANKTON STATION 4
5 58 73078652740000 385700762400
5 57 PLANKTON STATION 5
5 58 73079602400000 390400762000
5 57 PLANKTON STATION 6
5 58 73079611740000 391700761400
5 57 PLANKTON STATION 7
5 58 73079621200000 392200761000
5 57 PLANKTON STATION 8
5 58 73079620540000 392500760400
```

```
5 57 PLANKTON STATION 9
5 58 73079620723000 392730760200
5 57 X COVE POINT
5 58 73078622623000 382630762200
5 57 XI HOOPERS ISLAND
5 58 73078611560000 381500761600
5 59 042666   XXXX68  002  4  019
5 60 DON HEINLE
5 62 DAVE MORCK A
```

```
                         ******  M020001 ******
1  2 M020001
1  4 C BIO LAB
1  7 1972 PATUXENT RIVER SYNOPTIC PHYSICAL/CHEMICAL DATA SET
1 10 A SYNOPTIC VIEW OF A COASTAL PLAIN ESTUARY
1 14 NORTH AMERICA, U.S., COASTAL, MARYLAND, PATUXENT RIVER
1 17 AN EXTREMELY DENSE DATA SET.  SOME PARAMETERS ARE REPORTED HOURLY
1 17 FOR 24 HOURS, OTHER PARAMETERS FOR 3 DAYS (HOURLY).  THE ORIGINAL
1 17 DATA COLLECTION EFFORT INCLUDES SEVERAL PARAMETERS, E.G. TIDE,
1 17 CURRENT VELOCITY, AIR TEMP WHICH ARE NOT REPORTED IN THIS DATA SET
1 17    10            TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17   300            OXYGEN, DISSOLVED (MG/L)
1 17   480            SALINITY - PARTS PER THOUSAND
1 17   608            NITROGEN, AMMONIA, DISSOLVED (MG/L AS N)
1 17   625            NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   630            NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1 17   669            PHOSPHORUS, TOTAL HYDROLYZABLE (MG/L AS P)
1 17   671            PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
1 17   681            CARBON, DISSOLVED ORGANIC (MG/L AS C)
1 17 32209            CHLOROPHYLL A UG/L FLUOROMETRIC CORRECTED
1 17 32235            CHLOROPHYLL, TOTAL (SARGENT METHOD-667MU) UG/L
1 17 71100            SEDIMENT, SUSPENDED PARTICULATE (MG/L)
1 17 98764            NITROGEN, PARTICULATE (MG-AT/L AS N) <NSC>
1 17 98765            CARBON, PARTICULATE ORGANIC (?) <NSC>
1 18 ROBERT E. ULANOWICZ
1 19 301 326-4281
1 20 CHESAPEAKE BIOLOGICAL LABORATORY - CBL
1 21 P. O. BOX 38
1 22 SOLOMONS
1 23 MD
1 25 20688
1 27 2145 CARD IMAGES IN E-2 FORMAT
5 35 1                   00000
5 39 1                   00000
5 40 1                   00000
5 42 1                   00000
5 43 1                   00000
5 45 1                   00000
5 46 1                   00000
5 57  P-01-01
5 58 73078612854137 381843 762517
5 57  P-01-02
5 58 73078612855157 381855 762517
5 57 P-02-01
5 58 73078622095303 382050 762933
5 57 P-02-02
5 58 73078622190008 382100 762908
5 57 P-03-01
5 58 73078623454027 382442 763507
5 57 P-04-01
5 58 73078623993585 382938 763955
5 57 P-04-02
5 58 73078634203302 383230 764032
5 57 P-05-01
5 58 73078634404464 383446 764044
```

```
5 57 P-05-02
5 58 73078634912033 383923 764103
5 57 P-06-01
5 58 73078644223032 384640 764202
5 57 P-07-01
5 58 73078644624503 384640 764253
5 57 UNNAMED STA 1
5 58 73078634912033 383923 764103
5 57 UNAMED STA 2
5 58 73078634404464 383446 764044
5 57 UNNAMED STA 3
5 58 73078654711388 384640 764253
5 57 UNNAMED STA 4
5 58 73078654711480 385718 764140
5 59 721017 721019  24 D  12
5 60 ACCLIMATION        A
```

```
                             ****** M020002 ******
1  2 M020002
1  4 INTERSTATE COMMISSION ON THE POTOMAC RIVER BASIN
1  7 UPPER POTOMAC RIVER WATER QUALITY DATA
1 10 [PROJECT]
1 14 NORTH ATLANTIC, COASTAL, CHESAPEAKE BAY, POTOMAC RIVER
1 17 THIS DATA SET IS A COLLECTION OF MANY COLLECTIONS BY NUMEROUS AGENCIES.
1 17 THE DATA, AS MADE AVAILABLE TO THE PROJECT FROM CBI (HOPKINS),
1 17 CONTAINS MANY MANY PROBLEMS.
```

```
                 ****** M022001 ******
1  2 M022001
1  4 C BIO LAB
1  7 MIHURSKY, MCERLEAN, HERMAN  1967 NRI REF 67-59
1 10 COOPERATIVE ZOOPLANKTON INVESTIGATIONS IN THE PATUXENT RIVER
1 10 ESTUARY DURING THE PERIOD JULY 1963 - FEBRUARY 1965
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, PATUXENT RIVER
1 17 METHODS:  MENZEL, AUG 1962.  INSTRUCTION MANUAL FOR ROUTINE MEASUREMENTS
1 17 FOR U.S. PROGRAM IN BIOLOGY.  BERMUDA BIOL. STATION
1 17 TOTAL ZOOPLANKTON (THIS DATA NOT ENCODED):  NEOMYSIS AMERICANA, ACARTIA
1 17    CLAUSII, EURYTEMORA AFFINIS, ACARTIA TONSA, CTENOPHORE &
1 17    COELENTERATES. BREAKDOWN  BY STATIONS OF OTHERS
1 17 26 CRUISES, 8 (TOTAL)STATIONS SAMPLED FOR TEMP, SALININTY, TURBIDITY
1 17 4 STATIONS SAMPLED +- ONCE/MONTH FOR SAME PLUS NITRATE, PHOSPHATE,
1 17 SILICATE AND CHLOROPHYLL.  EXTRACTED FROM CRUISE NOTES AND LABORATORY
1 17 ANALYSIS RECORDS. SURFACE AND BOTTOM SAMPLES FOR MOST PARAMETERS.
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    75  TURBIDITY, HELLIGE (PPM AS SILICON DIOXIDE)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   955  SILICA, DISSOLVED (MG/L AS SIO2)
1 17   618  NITRATE NITROGEN, DISSOLVED (MG/L AS N)
1 17   666  PHOSPHORUS, DISSOLVED (MG/L AS P)
1 17   681  CARBON, DISSOLVED ORGANIC (MG/L AS C)
1 17 32209  CHLOROPHYLL A UG/L FLUOROMETRIC CORRECTED
1 18 DON HEINLE
1 19 301 326-4281
1 20 CHESAPEAKE BIOLOGICAL LAB - CBL
1 21 P. O. BOX 38
1 22 SOLOMONS
1 23 MD
1 25 20688
1 27 FILE SIZE IS 678 CARD IMAGES IN E-2 FORMAT
1 27 7 PARAMETERS MEASURED AT 4 STATIONS TWICE PER MONTH FOR 18 MOS
1 27 4 ADDITIONAL STATIONS SAMPLED WITH LESS FREQUENCY. SURFACE AND
1 27 BOTTOM SAMPLES FOR MOST PARAMETERS
5 35 1                    102
5 37 1                    336
5 39 1                    112
5 40 1                    112
5 41 1                    111
5 45 1                    534
5 46 1                    534
5 56  1841
5 57 LOWER MARLBORO 1-63
5 58 73078634903505 383930764055
5 57 POWER LINE 2-63
5 58 73078634700250 383705764020
5 57 TRUEMAN POINT 3-63
5 58 73078634402350 383425764030
5 57 CHALK POINT 4-63
5 58 73078634202350 383225764030
5 57 BENEDICT BRIDGE 5-63
5 58 73078634005200 383050764020
5 57 SHERIDAN POINT 6-63
5 58 73078623680555 382805763855
```

```
5 57 QUEEN TREE  7-63
5 58 73078623564300 382540763630
5 57 BROOMES ISLAND 8-63
5 58 73078623335300 382350763330
5 59 071863 020965 002 3 008
5 60 MARTHE COLE-JONES  A
5 62 MARTHE COLE-JONES A
```

```
                     ****** M022002 ******
1  2 M022002
1  4 US EPA REG 3
1  7 PATUXENT RIVER 1967 THRU 1970 WATER QUAL - EPA
1 10 WATER QUALITY SURVEY OF THE PATUXENT RIVER DATA REPORTS:
1 10 #15 (1967),#16 (1968),  #17 (1969),#34 (1970)
1 14 NORTH AMERICA, US. MARYLAND, COASTAL, PATUXENT RIVER
1 17 ALL DATA (1968-70) WAS PREVIOUSLY ENCODED BY EPA ; IN STORET
1 17 UNDER AGENCY CODE : 1113TXWQ
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    70  TURBIDITY, (JACKSON CANDLE UNITS
1 17    77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17    95  CONDUCTIVITY AT 25 DEGREES C (MIRCOMHOS)
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   310  BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
1 17   400  PH (STANDARD UNITS)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   610  NITROGEN, AMMONIA, TOTAL  (MG/L AS N)
1 17   625  NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   630  NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1 17   660  PHOSPHATE, ORTHO (MG/L AS PO4)
1 17   680  CARBON, TOTAL, ORGANIC (MG/L AS C)
1 17 32210  CHLOROPHYLL A, TRICHROMATIC UNCORRECED (UG/L)
1 17 71886  PHOSPHORUS, TOTAL, AS PO4 MG/L
1 17 REPORT INCLUDES 19 STATIONS 5 IN FRESH WATER
1 17 DATA FOR THE FRESH WATER STATIONS NOT TRANSCRIBED
1 17 1967 REPORT INCLUDES THE FOLLOWING DATA WHICH WAS NOT ENCODED:
1 17 (A) DAILY SAMPLING FOR +/- 9 DAYS AT 9 SEWAGE TREATMENT PLANTS IN UPPER
1 17 PATUXENT (FINAL EFFLUENT)
1 17(B) MONTHLY SAMPLING A 15 ADDITIONAL UPRIVER (FRESHWATER) STATIONS
1 17 1968 REPORT ALSO INCLUDES (WHICH WAS NOT ENCODED) A) INTENSIVE SAMPLING
1 17   AT 5 CONSECUTIVE DAYS AT 23 UPRIVER STATIONS (FRESHWATER) -DATA NOT ENCOD
1 17 B) 1 DAY SAMPLING AT 26 SEWAGE TREATMENT PLANTS
1 17 1969 (18 ESTUARINE STATIONS ONLY  -   ALL DATA ENCODED)
1 17 1970 REPORT INCLUDES 9 ADDITIONAL UPRIVER STATIONS (FRESHWATER) SAMPLED
1 17     ONCE FOR WHICH DATA WAS NOT ENCODED
1 17 ADDITIONAL FRESHWATER STATIONS ARE APPENDED TO 1970 DATA SET
1 17 1970 DATA NOT IN MONTHLY SEQUENCE
1 17 METHODS:
1 17 (1) D.O.  WINKLER, AZIDE MODIF., FWPCA, 1969.
1 17 (2) TOTAL PHOSPHORUS  MENZEL&CORWIN 1965, AND MURPHY & RILEY 1962
1 17 (3) INORGANIC PHOSPHORUS  AUTO ANALYZER - MURPHY AND RILEY 1962
1 17 (4) TKN  STANDARD METHODS FOR EXAMINATION OF WATER AND WASTEWATER 1965
1 17 (5) NO2 & NO3  STRICKLAND AND PARSONS 1968
1 17 (6) NH3  PHENOL-HYPOCLORITE, FWPCA METHODS  WATER AND WASTE WATER 1969.
1 17 (7) BOD  STANDARD METHODS, 1965
1 17 (8) TOC  FWPCA  1969
1 17 (9) CHL A  STRICKLAND AND PARSONS  1968
1 17 (10) PH  FIELD PH METER STANDARD UNITS
1 17 (11) SALINITY    BECKMAN SALINOMETER  PPT
1 17 (12) CONDUCTIVITY   BECKMAN SALINOMETER  MICROMHOS
1 18 JAMES W. MARKS/O. VILLA, JR.
1 19 301-224-2740
1 20 ANNAPOLIS FIELD OFFICE - EPA
1 22 ANNAPOLIS
```

```
1 23 MD
1 25 21401
1 27 18 STATIONS RECORDED, MONTHLY CRUISE SAMPLED FOR TEMP, TOTAL P,
1 27 INORG P, TKN, NO2+NO3, NH3, CHL, OCCASSIONALLY BOD, TOC
1 27 4 YEAR DURATION
5 35 1 CHL A              307
5 37 1                    142
5 38 1                    323
5 39 1 TOTAL & INORG      700
5 40 1 TKN,AMMON,NO2,NO3  930
5 42 1 TOTAL               53
5 45 1                    385
5 46 1                     30
5 49 1 5-DAY               49
5 53 1 CONDUCTIVITY        30
5 54 1 SECCHI              65
5 57 WAYSONS CORNER 5-70
5 58 73078644920000 384900764200
5 57 SEWAGE T. PLANT 5B-70
5 58 73078644733000 384730764300
5 57 WESTERN BRANCH MOUTH 6-70
5 58 73078644720405 384700764245
5 57 CHANNEL/JUG BAY 6A-70
5 58 73078644610300 384600764130
5 57 MOUTH/LYONS CREEK 7-70
5 58 73078644223005 384500764205
5 57 NOTTINGHAM 8-70
5 58 73078644223005 384230764205
5 57 LOWER MARLBORO 9-70
5 58 73078634903505 383930764055
5 57 HIGH POWER LINE 10-70
5 58 73078634700250 383705764020
5 57 TRUEMAN/DEEP LANDING 11-70
5 58 73078634500400 383500764040
5 57 POTTS POINT 12-70
5 58 73078634303300 383330764030
5 57 PEPCO CANAL/MOUTH 12A-70
5 58 73078634304455 383345764045
5 57 CHALK POINT 13-70
5 58 73078634202350 383225764030
5 57 BENEDICT BRIDGE 14-70
5 58 73078634005200 383050764020
5 57 SHERIDAN POINT 15-70
5 58 73078623785503 382750763853
5 57 ROUTE 50 BRIDGE
5 58 73078654720000 385700764200
5 57 QUEEN ANNES BRIDGE
5 58 73078654400300 385400764030
5 57 BELLS JUNK YARD
5 58 73078654201450 385215764040
5 57 TRAILER COURT
5 58 73078644930000 384900764300
5 59 032067 112370    1 3  18
5 60 MARTHE COLE-JONES    A
```

```
                    ******  M022003 ******
1  2 M022003
1  4 C BIO LAB
1  7 D.A. FLEMER ET AL, NRI REF 71-6, 71-6B
1 10 EFFECTS OF THERMAL LOADING AND WATER QUALITY ON ESTUARINE PRIMARY
1 10 PRODUCTIVITY OF THE PATUXENT RIVER 1968 - 1971
1 14 NORTH AMERICA, U.S., MARLAND, COASTAL, PATUXENT RIVER
1 17  - METHODS 1) CHL A LORENZEN 1966, HOLM-HANSEN ET AL 1965
1 17 2) PARTICULATE AND DISSOLVED CARBON - MENZEL AND VACCARO 1964
1 17 3) PARTICULATE CARBOHYDRATE - STRICKLAND & PARSONS 1968
1 17 4) TOTAL PHOSPHORUS - MENZEL AND CORWIN 1965
1 17 5) DISSOLVED INORGANIC PHOSPHORUS - STRICKLAND AND PARSONS 1968
1 17 6) AMMONIA, NITRATE, NITRITE - STRICKLAND AND PARSONS 1968
1 17 7) TKN -MODIFIED STRICKLAND AND PARSONS 1968
1 17     10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17     78  TRANSPARENCY, SECCHI DISC (METERS)
1 17    300  OXYGEN, DISSOLVED (MG/L)
1 17    480  SALINITY - PARTS PER THOUSAND
1 17    600  NITROGEN, TOTAL (MG/L AS N)
1 17    602  NITROGEN, DISSOLVED (MG/L AS N)
1 17    607  NITROGEN, ORGANIC, DISSOLVED (MG/L AS N)
1 17    608  NITROGEN, AMMONIA, DISSOLVED (MG/L AS N)
1 17    613  NITRITE NITROGEN, DISSOLVED (MG/L AS N)
1 17    618  NITRATE NITROGEN, DISSOLVED (MG/L AS N)
1 17    681  CARBON, DISSOLVED ORGANIC (MG/L AS C)
1 17    665  PHOSPHORUS, TOTAL (MG/L AS P)
1 17    666  PHOSPHORUS, DISSOLVED (MG/L AS P
1 17    671  PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
1 17 32209  CHLOROPHYLL A UG/L FLUOROMETRIC CORRECTED
1 17 71100  SEDIMENT, SUSPENDED PARTICULATE (MG/L)
1 17 98763  CARBOHYDRATE, PARTICULATE (MG/L AS SUCROSE)
1 17 98764  NITROGEN, PARTICULATE (MG/L AS N) <NSC>
1 17 98765  CARBON, PARTICULATE ORGANIC ( ) <NSC>
1 17 FINAL REPORT ON THE EFFECTS OF THERMAL LOADING AND WATER QUALITY
1 17   ON ESTUARINE PRIMARY PRODUCTION 1968-1969-1970-1971
1 17   STATIONS 1 - 9 SURFACE ONLY
1 17   STATIONS 10-14 SURFACE AND BOTTOM
1 18 DONALD HEINLE/D.A. FLEMER
1 19 301 326-4281
1 20 CHESAPEAKE BIOLOGICAL LABORATORY - CBL
1 21 P. O. BOX 38
1 22 SOLOMONS
1 23 MD
1 25 20688
1 27 2918 RECORDS
1 27 18 PARAMETERS MEASURED APPROX 2 TIMES PER MONTH FOR 27 MONTHS
1 27 AT 14 STATIONS.  ALL SAMPLED SURFACE, 4 STATIONS ALSO SAMPLED BOTTOM.
5 35 1 CHL A              430
5 37 1 SECCHI             430
5 38 1                    350
5 39 1 DIP TDP TP         904
5 40 1 NO3,NO2,NH3,DON,DN1690
5 42 1 DISS               147
5 43 1 SESTON             430
5 45 1
```

```
5 46 1
5 53 1 PART CARBON        406
5 54 1 PART CARBOHYDR     438
5 55 1 PART NITROGEN      352
5 57 HILLS BRIDGE 1 - 68
5 58 73078644920000 384900764200
5 57 RAIN WATER CREEK 2-68
5 58 7307864473300  384730764300
5 57 WESTERN BRANCH 3-68
5 58 73078644720405 384700764245
5 57 JUG BAY 4-68
5 58 73078644610300 384600764130
5 57 FENNO MARSH 5-68
5 58 73078644510200 384500764120
5 57 NOTTINGHAM 6-68
5 58 73078644223005 384230764205
5 57 LOWER MARLBORO 7-68
5 58 73078634903505 383930764055
5 57 COCKTOWN CREEK 8-68
5 58 73078634704550 383745764050
5 57 DEEP LANDING 9-68
5 58 73078634504250 383545764020
5 57 TRUEMAN POINT 10-68
5 58 73078634402350 383425764030
5 57 EFFLUENT SES 11-68
5 58 73078634303300 383330764030
5 57 CHALK POINT 12-68
5 58 73078634202350 383225764030
5 57 BENEDICT BRIDGE 13-68
5 58 73078634005200 383050764020
5 57 QUEEN TREE 14-68
5 58 73078623263350 382235763630
5 59 081868 110671   2 3  14
5 60 DON HEINLE          A
5 62 MARTHE COLE-JONES A
```

```
                              ****** M022004 ******
1  2 M022004
1  4 C BIO LAB
1  7 EARLY CHES BIOL LAB PIER DATA 1938-43
1 14 NORTH AMERICA,US,MARYLAND, COASTAL,PATUXENT RIVER
1 17 THIS STATION SAMPLED WITH GREATER FREQUENCY IN EARLY YEARS WHEN
1 17   SAMPLED DAILY.  41,42,43 SAMPLED ABOUT 2 X / MO
1 17 METHODS  -   PHOSPHATE - NEWCOMBE AND LANG 1939
1 17 SILICATE - COLOROMETRIC, MOLYBDATE COMPLEX METHOD
1 17     10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17     20  TEMPERATURE, AIR (DEGREES CENTIGRADE)
1 17     78  TRANSPARENCY, SECCHI DISC (METERS)
1 17    955  SILICA, DISSOLVED (MG/L AS SIO2)
1 17    300  OXYGEN, DISSOLVED (MG/L)
1 17    400  PH (STANDARD UNITS)
1 17    480  SALINITY - PARTS PER THOUSAND
1 17    669  PHOSPHORIS, TOTAL HYDROLYZABLE (MG/L AS P)
1 17 70205  TIDE, RANGE (FEET) BETWEEN ADJACENT HIGH - LOW TIDES
1 18 DON HEINLE
1 19 301-326-3281
1 20 CHESAPEAKE BIOLOGICAL LABORATORY - CBL
1 21 P. O. BOX 38
1 22 SOLOMONS
1 23 MD
1 25 20688
1 27 7 PARAMETERS MEASURED MORE OR LESS 5 DAYS / WEEK FOR 5 YRS.
1 27 TEMPERATURE, SALINITY, D.O. MEASURED WITH GREATEST FREQUENCY
5 38 1                  486
5 39 1 DISS PHOSPHATES  366
5 41 1 DISS SILICATES    35
5 45 1                  393
5 46 1                  372
5 48 1                  162
5 53 1 AIR TEMP         285
5 54 1 TIDE HEIGHT      252
5 55 1 SECCHI           146
5 57 PIER OF CHES BIOL LAB  6-36
5 58 73078612970055 381905762705
5 59 061238 062443 005 4 001
5 60 DON HEINLE           A
5 62 KAY MILLSAPS       A
```

```
                          ******  M022005 ******
1  2 M022005
1  4 C BIO LAB
1  7 EARLY CHES BIOL LAB CRUISE DATA 1936 - 1939
1 10 EARLY CHES BIOL LAB CRUISE DATA 1936 - 1939
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, PATUXENT RIVER &
1 14 CHESAPEAKE BAY
1 17 METHODS OF ANALYSIS (PO4, NO2, ETC. ) VARIABLE THROUGH TIME
1 17 1936-37 ( 14 STA ) RIVER STATIONS SAMPLED PRIMARILY.
1 17 1938-39 (10 STA) BAY STATIONS SAMPLED PRIMARILY.
1 17 OCCASSIONAL TRIPS: ANNAPOLIS AND MOUTH OF BAY (CAPES)
1 17 SURFACE , MID DEPTH AND BOTTOM SAMPLED.  SOME CLOSE INTERVALS,
1 17 SOME DIURNAL STUDIES
1 17 METHODS COMMENTS:
1 17 1)DISSOLVED OXYGEN - TITRATION ( WINKLER 1888 )
1 17 2) DISSOLVED ORTHOPHOSPHATES - COLORMETRIC CERULEOMOLYBDATE COMPLEX;
1 17 2) (NEWCOMBE AND LANG, 1939 )
1 17 3) NITRITE  NITROGEN DISSOLVED ( RAKESTRAW, 1936 ) P 135
1 17 3) WOODS HOLE REPRINTS, SULFANILMIDE - DIAZONIUM SALT; COLOROMETRIC ?
1 17 4) SILICATES; DISSOLVED - COLORMETRIC MOLYBDATE COMPLEX
1 17 5) SALINITY - TITRATION W/SIVER NITRATE
1 17 6) CHEMICAL OXYGEN DEMAND - PERMANGANATE AS OXIDIZING AGENT, FOLLOWED BY
1 17 6) BY TITRATION
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17    78  TRANSPARENCY, SECCHI DISC (METERS)
1 17    95  CONDUCTIVITY AT 25 DEGREES C (MIRCOMHOS)
1 17   400  PH (STANDARD UNITS)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   955  SILICA, DISSOLVED (MG/L AS SIO2)
1 17   613  NITRITE NITROGEN, DISSOLVED (MG/L AS N)
1 17   618  NITRATE NITROGEN, DISSOLVED (MG/L AS N)
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   669  PHOSPHORUS, TOTAL HYDROLYZABLE (MG/L AS P)
1 17 74010  IRON, TOTAL ( MG/L AS FE)
1 17 98761  CHEMICAL OXYGEN DEMAND, DISSOLVED, KMNO4, ( MG O2 CONSUMED / L )
1 17 98765  CARBON, PARTICULATE ORGANIC (?) <NSC>
1 18 DON HEINLE
1 19 301) 326 - 4281
1 20 CHESAPEAKE BIOLOGICAL LABORATORY - CBL
1 21 P.O. BOX 38
1 22 SOLOMONS
1 23 MD
1 25 20688
1 27 3277 RECORDS
5 37 1 SECCHI              223
5 38 1                    1275
5 39 1 DISSOLVED          1199
5 40 1 NO2,NO3             744
5 41 1 DISSOLVED           672
5 45 1                    1588
5 46 1                    1452
5 48 1                    1071
5 51 1 KMNO4               108
5 57 FISH SPARS 1-36 (103-39)
```

```
5 58 73078611553000 381530761500
5 57 OPPOSITE BARREN I 2-36 (101-39)
5 58 73078611984550 381945761850
5 57 CEDAR POINT 3-36 (102-39)
5 58 73078612901105 381910762015
5 57 NW CEDAR POINT 4-36
5 58 73078612924550 381945762250
5 57 DRUM POINT 5-36
5 58 73078612950105 381900762515
5 57 CBL LAB PIER 6-36
5 58 73078612970055 381905762705
5 57 SANDY POINT 7-36
5 58 73078612874350 381845762730
5 57 POINT PATIENCE   8-36
5 58 73078612994105 381940762915
5 57 HOOPERS NECK 9-36
5 58 73078622191205 382110762925
5 57 ST. CUTHBERT'S 10-36
5 58 73078623105100 382150763010
5 57 S BY SW ST. CUTHBERTS 10A-36
5 58 73078622192550 382125762950
5 57 BROOMES ISLAND 12-36
5 58 73078623335300 382350763330
5 57 QUEEN TREE 13-36
5 58 73078623565400 382550763640
5 57 SHERIDAN POINT 14-36
5 58 73078623880555 382805763855
5 57 LONG POINT 15-36
5 58 73078624903000 382930764000
5 57 TOWN POINT 16-36
5 58 73078634005000 383050764000
5 57 TEAGUE POINT 17-36
5 58 73078633194555 383145763955
5 57 GODS GRACE POINT 18-36
5 58 73078634202350 383225764030
5 57 POTTS POINT 19-36
5 58 73078634304300 383340764030
5 57 DEEP LANDING 20-36
5 58 73078634500400 383500764040
5 57 HOLLAND CLIFF 21-36
5 58 73078634704550 383745764050
5 57 MARLBORO
5 58 73078634903505 383930764055
5 57 HOOPERS IS LT 3-38 (103-39)
5 58 73078611563300 381530761630
5 57 OFF TARGETS 4-38
5 58 73078611363000 381330761600
5 57 BLOODSWORTH IS 5-38 (105-39)
5 58 73078601773300 380730761730
5 57 SMITH ISLAND 6-38 (106-39)
5 58 73078601233300 380230761330
5 57 POINT LOOKOUT 7-38 (107-39)
5 58 73078601273105 380230761715
5 57 POINT NO POINT 8-38 (108-39)
5 58 73078601871050 380815761700
```

```
5 57 COVE POINT (110-39)
5 58 73078622321005 382310762205
5 57 TAYLORS I 205-38 (63-37)
5 58 73078622614455 382645762145
5 57 DARES BEACH 210-38
5 58 73078632364155 383345762615
5 57 BLACKWALNUT PT 215-38
5 58 73078642053100 384030762510
5 57 POPLAR IS 220-38
5 58 73078642465050 384455762600
5 57 KENT POINT 225-38
5 58 73078652041250 385015762420
5 57 BRICKHOUSE BAR 230-38
5 58 73078652630005 385600762305
5 57 SANDY POINT
5 58 73079602033000 390030762300
5 57 SMITH POINT 160-38
5 58 73077651343000 375330761400
5 57 FLEET POINT 170-38
5 58 73077641863000 374830761600
5 57 NEW POINT COMFORT 180-38
5 58 7307761191000 3719007611000
5 57 CAPE HENRY 190-38
5 58 73076555870300 365800755730
5 57 BUOY R-8 6A MOUTH PAT
5 58 73078612872030 381823762700
5 57 110A COVE PT TRANS
5 58 73078622331000 382310762300
5 57 110B COVE PT TRANS
5 58 73078622321305 382310762235
5 57 110C COVE PT TRANS
5 58 73078622311300 382310762130
5 57 110D COVE PT TRANS
5 58 73078622301400 382310762040
5 57 110E COVE PT TRANS
5 58 73078621391105 382310761915
5 57 110F COVE PT TRANS
5 58 73078621381205 382310761825
5 57 110G COVE PT TRANS
5 58 73078621371100 382310761710
5 57 108A PT NO PT TRANS
5 58 73078601890055 380805761905
5 57 108B PT NO PT TRANS
5 58 73078601880150 380805761810
5 57 108C PT NO PT TRANS
5 58 73078601870155 380805761715
5 57 108D PT NO PT TRANS
5 58 73078601860350 380805761630
5 57 108E PT NO PT TRANS
5 58 73078601850052 380805761502
5 57 108F PT NO PT TRANS
5 58 73078601830550 380805761350
5 57 108G PT NO PT TRANS
5 58 73078601820055 380805761205
5 57 108H PT NO PT TRANS
```

```
5 58 73078601800450 380805761040
5 57 1081 PT NO PT TRANS
5 58 73078600870150 380805760710
5 57 301 COVE PT TRANS
5 58 73078622321005 382310762205
5 57 302 COVE PT TRANS
5 58 73078622311300 382310762130
5 57 303 COVE PT TRANS
5 58 73078622301400 382310762040
5 57 304 COVE PT TRANS
5 58 73078621391400 382310761940
5 57 305 COVE PT TRANS
5 58 73078621381105 382310761815
5 57 306 COVE PT TRANS
5 58 73078621183455 382135761845
5 57 307 COVE PT TRANS
5 58 73078622014455 382045762145
5 59 070736 081639 002 3
5 60 DON HEINLE         A
5 62 MARTHE COLE-JONES A
```

```
                         ****** M022006 ******
 1  2 M022006
 1  4 US EPA REG 3
 1  7 WATER QUALITY SURVEY OF THE UPPER CHESAPEAKE BAY 1969 -1970 -1971
 1  7 DATA REPORT # 24.
 1 14 NORTH AMERICA, U.S. MARYLAND, COASTAL, CHESAPEAKE BAY
 1 17 ALL STATIONS (#'S 2-11) IN STORET:; DATA FOR ONLY 1970-71
 1 17 ENCODED BY EPA  ;DATA AVAILABLE IN STORET UNDER AGENCY CODE : 11121AWQ
 1 17 METHODS:
 1 17 1)CONDUCTIVITY - CALIBRATED BECKMAN SALINOMETER
 1 17 2)TOTAL PHOSPHORUS - MENZEL AND CORWIN 1965
 1 17 2) MURPHY AND RILEY 1962
 1 17 3) INORGANIC PHOSPHORUS - MURPHY AND RILEY W/AUTOANALYZER
 1 17 4) TKN - STANDARD METHODS 1965
 1 17 5 ) NO2,NO3 STRICKLAND AND PARSONS 1968
 1 17 6) NH3 FWCPA CHEMICAL ANALYSIS OF WATER AND WASTE 1969
 1 17 7) DO - STANDARD METHODS 1965,  FWCPA 1969
 1 17 8) CHL A STRICKLAND AND PARSONS 1968
 1 17    10          TEMPERATURE, WATER (DEGREES CENTIGRADE)
 1 17    77          TRANSPARENCY, SECCHI DISC (INCHES)
 1 17   300          OXYGEN, DISSOLVED (MG/L)
 1 17   400          PH (STANDARD UNITS)
 1 17   480          SALINITY - PARTS PER THOUSAND
 1 17   610          NITROGEN, AMMONIA, TOTAL (MG/L AS N)
 1 17   625          NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
 1 17   630          NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
 1 17   650          PHOSPHATE, TOTAL (MG/L AS PO4)
 1 17   660          PHOSPHATE, ORTHO (MG/L AS PO4)
 1 17 32211          CHLOROPHYLL A (UG/L) SPECTROPHOTOMETRIC METHOD
 1 17 PHOSPHOROUS INCLUDES TOTAL P AND INORG P
 1 17 NITROGEN INCLUDES TKN,NO2,NO3,NH3
 1 18 JAMES W. MARKS
 1 19 301 224-2740
 1 18 OTERIO VILLA, JR.
 1 20 EPA ANNAPOLIS FIELD OFFICE
 1 22 ANNAPOLIS
 1 23 MD
 1 25 21401
 1 27 602 RECORDS
 1 27 10 STATIONS SAMPLED ONCE A MONTH FOR 3-5 MONTHS EACH YEAR FOR 11 PARAMETERS
 5 35 1 CHL A              90
 5 37 1 SECCHI             78
 5 38 1                   163
 5 39 1 TOTAL AND INORG   339
 5 40 1 TKN, NO2+NO3, NH3 507
 5 45 1                   158
 5 46 1                   133
 5 48 1                    16
 5 57 T-2 SASSAFRAS
 5 58 73079620350300 392300760530
 5 57 T-3 SPESUTIE CHANN
 5 58 73079620831182 392818760312
 5 57 T-4 STILLPOND BUOY
 5 58 73079621004188 392048761018
 5 57 T-5 ROMNEY CK BUOY
```

```
5 58 73079621104380 392148761030
5 57 T-6 FAIRLEE CK BUOY
5 58 73079601795162 390756761912
5 57 T-7 LOWER POOLES I
5 58 73079611651524 391612761554
5 57 T-8 BUOY S#41B
5 58 73079611683204 391630761824
5 57 T-9 BUOY R#16
5 58 73079611160402 391100761642
5 57 T-10 BUOYS CS/S#18B
5 58 73079612220408 391200762248
5 57 T-11 HORN/NORTH PT
5 58 73079612131491 391119762341
5 59 062469 081671 001 3 010
5 60 DON HEINLE          A
5 62 BUD MILLSAPS       A
```

```
                    ****** M022007 ******
1  2 M022007
1  4 US EPA REG 3
1  7 CHESAPEAKE  BAY NURTIENT INPUT STUDY TECHNICAL REPORT # 47 SEPT 72
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, CHESAPEAKE BAY& ITS MAJOR TRIBS
1 17 MAJOR TRIBUTARIES OF CHES BAY INCLUDE  SUSQUEHANNA, PATUXENT, POTOMAC,
1 17   RAPPAHANNOCK, YORK (MATTAPONI & PAMUNKEY), JAMES, CHICKAHOMINY
1 17 REPORT MAY BE USEFUL FOR DESCRIPTION OF TRENDS, ETC., BUT
1 17    BUT NOT USEFUL FOR INDEX DEVELOPMENT, ETC., AS DATA IS REPORTED
1 17   AS NUTRIENT LOADINGS IN LBS/DAY, ETC.
1 18 VICTOR GUIDE/ORTERIO VILLA, JR.
1 19 301 224-2740
1 20 EPA ANNAPOLIS FIELD OFFICE
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
5 60 MARTHE COLE-JONES   U
5 63 DATA NOT EXPRESSED IN USABLE FORM  -  DATA EXPRESSED AS NUTRIENT
5 63    LOADINGS LBS/DAY OR AS MEAN MONTHLY LOADINGS IN MG/L.
```

```
                    ****** M022008 ******
1  2 M022008
1  4 US EPA REG 3
1 10 COOPERATIVE BACTERIOLOGICAL STUDY UPPER CHES BAY DREDGING SPOIL DISPOSAL
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY
1 17 ALL SAMPLES WERE TAKEN BETWEEN 1400 AND 1600 HRS BUT TIMES  WERE NOT
1 17   RECORDED FOR INDIVIDUAL SAMPLES.
1 17 BACTERIAL PLATE COUNTS WERE MADE ON PLATES OF DIFCO DEHYDRATED PLATE
1 17   COUNT AGAR INOCULATED BY THE STREAK PLATE METHOD AND INCUBATYED AT 20 C
1 17   FOR 36 HRS.  PLATE COUNTS WERE GIVEN AS BACTERIA PER ML.
1 17 COLIFORMS AND FECAL COLIFORMS WERE ESTIMATED BY A "5-TUBE-3-DILUTION
1 17    MOST-PROBABLE METHOD" TECHNIQUE.  COUNTS WERE GIVEN AS BACTERIA
1 17    PER 100ML.
1 17 TURBIDITY EXPRESSED IN JACKSON TURBIDITY UNITS WAS DETERMINED USING
1 17    USING A HACH NEPHELOMETRIC PHOTOELECTRIC TURBIDIMETER.
1 17 IN ADDITION TO THESE PARAMETERS THE REPORT GIVES BACTERIAL GROWTH
1 17    AT 37 C AS EVIDENCED BY TURBIDITY IN LAURYL SULFATE TRYPTOSE BROTH.
1 17    THIS PARAMETER WAS NOT CODED.
1 17    70  TURBIDITY (JACKSON CANDLE UNITS)
1 17 31505  COLIFORM, TOTAL, MPN, CONFIRMED TEST 35 C (TUBE 31506)
1 17 31615  FECAL COLIFORM, MPN,EC MED, 44.5 C (TUBE 31614)(MPN/100ML)
1 17 98759  PLATE COUNT ,TOTAL, BACTERIA, TPC AGAR, 20 C, 36 HRS
1 18 LIBRARIAN
1 19 301 224-2740
1 20 ANNAPOLIS FIELD OFFICE, ENVIRONMENTAL PROTECTION AGENCY
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 22 STATIONS SAMPLED 1 DAY FOR 4 PARAMETERS:  SECCHI, COLIFORMS, FECAL
1 27    COLIFORMS, PLATE COUNT BACTERIA,   AT 2 DEPTHS.
5 37 1                    44
5 44 1                    44
5 53 1 BACT PLATE COUNT   44
5 54 1 FECAL COLIFORMS    44
5 57 TRANSECT 1 STATION 1
5 58 73079620191108 392110760918
5 57 TRANSECT 1 STATION 2
5 58 73079620192300 392120760930
5 57 TRANSECT 1 STATION 3
5 58 73079620193438 392133760948
5 57 TRANSECT 1 STATION 4
5 58 73079621104020 392142761000
5 57 TRANSECT 1 STATION 5
5 58 73079621105144 392154761014
5 57 TRANSECT 2 STATION 1
5 58 73079620093492 392039760942
5 57 TRANSECT 2 STATION 2
5 58 73079621005040 392054761000
5 57 TRANSECT 2 STATION 3
5 58 73079621101158 392115761018
5 57 TRANSECT 2 STATION 4
5 58 73079621102310 392121761030
5 57 TRANSECT 2 STATION 5
5 58 73079621103402 392130761042
```

```
5 57 TRANSECT 3 STATION 1
5 58 73079621002083 392028761003
5 57 TRANSECT 3 STATION 2
5 58 73079621004120 392042761010
5 57 TRANSECT 3 STATION 3
5 58 73079621100368 392106761038
5 57 TRANSECT 3 STATION 4
5 58 73079621100544 392104761054
5 57 TRANSECT 4 STATION 1
5 58 73079621001184 392018761014
5 57 TRANSECT 4 STATION 2
5 58 73079621003330 392033761030
5 57 TRANSECT 4 STATION 3
5 58 73079621005511 392051761051
5 57 TRANSECT 4 STATION 4
5 58 73079621110192 392109761112
5 57 TRANSECT 5 STATION 1
5 58 73079621000264 392006761024
5 57 TRANSECT 5 STATION 2
5 58 73079621001386 392018761036
5 57 TRANSECT 5 STATION 3
5 58 73079621014046 392044761106
5 57 TRANSECT 5 STATION 4
5 58 73079621110204 392100761124
5 59 112167 112167 001 0 022
5 60 DON HEINLE         A
5 62 H.S. MILLSAPS     A
```

```
                    ****** M022009 ******
1  2 M022009
1  4 US EPA REG 3
1  7 WATER QUATLITY SURVEY OF NORTHEAST RIVER, ELK RIVER, C&D CANAL,
1  7 BOHEMIA RIVER, SASSAFRAS RIVER AND UPPER CHESAPEAKE BAY, SUMMER 1968.
1  7 WATER QUALITY SURVEY OF THE HEAD OF THE CHESAPEAKE BAY
1  7 MARYLAND TRIBUTARIES DATA REPORT #12 (1969), #23 (1970-71)
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY AND TRIBS
1 17 1969 PHYTOPLANKTON DATA NOT ENCODED
1 17 DATA APPEARS TO BE IN STORET UNDER AGENCY CODE: 11123OWQ
1 17 STATION LOCATIONS OF #'S 2,5,6,7,8,9,10,12,13 WERE CHANGED
1 17 IN 1971 REPORT,STORET DOESN'T RECOGNIZE THESE CHANGES, INDICATING
1 17 THAT 1968-69-70 SAMPLES WERE AT NEW (1971) LOCATIONS, WHICH IS UNTRUE
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    70  TURBIDITY (JACKSON CANDLE UNITS)
1 17    77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17    95  CONDUCTIVITY AT 25 DEGREES C (MIRCOMHOS)
1 17   299  OXYGEN, DISSOLVED, ( ELECTRODE ) ( MG/L )
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   310  BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
1 17   400  PH (STANDARD UNITS)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   610  NITROGEN, AMMONIA, TOTAL  (MG/L AS N)
1 17   625  NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   629  NITROGEN, ORGANIC, KJELDAHL, TOTAL, (MG/L AS N)
1 17   630  NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1 17   660  PHOSPHATE, ORTHO (MG/L AS PO4)
1 17   680  CARBON, TOTAL ORGANIC (MG/L)
1 17 31506  COLIFORM, TOTAL, MPN, CONFIRMED TEST, TUBE CONFIG. (MPN/100ML)
1 17 31615  FECAL COLIFORM, MPN, EC MED, 44.5 C (TUBE 31614)(MPN/100ML)
1 17 32211  CHLOROPHYLL A (UG/L) SPECTROPHOTOMETRIC METHOD
1 17 32221  CHLOROPHYLL-A, % OF (PHEOPHYTON-A + CHLOROPHYLL-A),SPEC-ACID
1 17 71886  PHOSPHORUS, TOTAL AS PO4 (MG/L)
1 17 WATER TEMP  1968 YSI THERMISTOR OF DO PROBE
1 17 1969 BECKMAN SALINOMETER 1970-71 MERCURY THERM AND SALINOMETER
1 17 PH  BECKMAN N-I METER;   1969 - FIELD PH METER
1 17 DO   WINKLER (STAND METH) AND YSI D.O. METER (IN SITU=YSI 00299 PROBE)
1 17 BOD   STANDARD METHODS
1 17 TURBIDITY JTU  HACK PHOTOELECTRIC NEPHELOMETER
1 17 SALINITY   1968 HYDROMETERS;  1969-70 BECKMAN SALINOMETER
1 17 LIGHT EXTINCTION   SECCHI DISK
1 17 TOTAL PHOSPHORUS    MENZEL& CORWIN(1965); MURPHY&RILEY(1962)
1 17 NO2 & NO3   1968 - WOOD(1967);    1969-70-71 - STRICKLAND AND PARSONS
1 17 TOTAL KJELDAHL NITROGEN (TKN)     STANDARD METHODS
1 17 CHLORAPHYLL A    STRICKLAND AND PARSONS
1 17 CONDUCTIVITY    1969  BECKMAN SALINOMETER
1 17 PHAEOPIGMENTS (% CHL A)   STANDARD METHODS
1 17 INORGANIC PHOSPHORUS             MURPHY & RILEY(1962)
1 17 AMMONIA         1969-70-71   FWPCA
1 17 TOTAL ORGANIC CARBON         1970-71     FWPCA 1971
1 17 COLIFORMS    MULTIPLE TUBE FERM    1970-71 STANDARD METHODS
1 17 FECAL COLIFORMS    E.C.     1970-71  STANDARD METHODS
1 18 ORTERIO VILLA, JR.
1 19 301 224-2740
1 20 ANNAPOLIS FIELD OFFICE - EPA
```

```
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 17 STATIONS SAMPLED 3 TO 7 TIMES A YEAR (1 YR FOR 28 STATIONS)
1 27   FOR APPROX 14 PARAMETERS
1 27   1969 - 1 TIME PER WEEK FOR 3 SEPARATE WEEKS
5 35 1 CHL A              281
5 37 1                     76
5 38 1                    440
5 39 1 TP, IP             800
5 40 1 NO2,NO3,TKN,NH3,ON1376
5 44 1 COLIFORM            33
5 45 1                    417
5 46 1                     91
5 48 1                     31
5 49 1                     76
5 53 1 SECCHI             271
5 54 1 FECAL COLIFORMS     33
5 55 1 CONDUCTIVITY        96
5 57 SASSAFRAS RIVER, BRIDGE AT GEORGETOWN
5 58 73079525134080 392148755300
5 57 SASSAFRAS RIVER, NUN 6
5 58 73079525283000 392230755800
5 57 SASSAFRAS RIVER, CAN 3
5 58 73079525280466 392206755846
5 57 SASSAFRAS RIVER, OFF BETTERTON
5 58 73079620235435 392253760345
5 57 BAY, MIDWAY BETWEEN NUN 2 AND BELL 1
5 58 73079620334182 392348760312
5 57 BAY, TURKEY POINT, NUN 6
5 58 73079525693498 392639755948
5 57 ELK RIVER, NUN 10
5 58 73079525960366 392906755636
5 57 BOHEMIA RIVER, NUN 2
5 58 73079525833264 392836755324
5 57 BOHEMIA RIVER, ABOVE BRIDGE
5 58 73079525711452 392715755142
5 57 ELK RIVER, CAN 15
5 58 73079535122448 393124755248
5 57 C & D CANAL, NUN 26
5 58 73079535114420 393142755140
5 57 ELK RIVER, NUN 6
5 58 73079535312340 393324755130
5 57 ELK RIVER, NUN 14
5 58 73079535410006 393400755106
5 57 NORTHEAST RIVER, NUN 2
5 58 73079525991556 392915755956
5 57 NORTHEAST RIVER, NUN 10
5 58 73079535274441 393244755741
5 57 NORTHEAST RIVER NUN 18
5 58 73079535465405 393450755645
5 57 NORTHEAST RIVER, MOUTH OF CREEK
5 58 73079535563589 393538755659
5 57 T- 1 SASSAFRAS RIVER, OFF BETTERTON
```

```
5 58 73079620234482 392248760342
5 57 T- 2 BAY, NORTH OF CHANNEL, BETWEEN N2 AND N4
5 58 73079620351386 392318760536
5 57 T- 3 BAY  N2, ENTRANCE SPESUTIE NARROWS CHANNEL
5 58 73079620551422 392512760542
5 57 T- 4 BAY  BUOY 22, OFF STILL POND
5 58 73079621004188 392048761018
5 57 T- 5 BAY BUOY C1 OFF ROMNEY CREEK
5 58 73079621104326 392142761036
5 57 T- 6 BAY BUOY 12 OFF FAIRLEE CREEK
5 58 73079611544182 391548761412
5 57 T- 7 BAY BUOY C3 LOWER TIP POOLES ISLAND
5 58 73073691166010 391612761600
5 57 T- 8 BAY BUOY S41B, BETWEEN POOLES ISLAND AND MOUTH OF GUNPOWDER
5 58 73079611683204 391630761824
5 57 T- 9 BAY BUOY R6
5 58 73079601985142 390954761812
5 57 T-10 BAY BETWEEN C5 AND S 18B
5 58 73079612003564 391036762054
5 57 T-11 BAY OFF CRAIGHILL CHANNEL LIGHT
5 58 73079612131482 391118762342
5 57 2-71 SASSAFRAS N8
5 58 73079525251437 392213755547
5 57 5-71 POND CREEK R4
5 58 73079620511252 392515760122
5 57 6-71 ARNOLD POINT R8
5 58 73079525785079 392757755809
5 57 7-71 LONG POINT R2 BOHEMIA
5 58 73079525833438 392833755348
5 57 8-71 BOHEMIA ABOVE BRIDGE
5 58 73079525722072 392727755202
5 57 9-71 BUOY 13 OLDTOWN WHARF ELK
5 58 73079535052102 393020755512
5 57 10-71 WELCH POINT BUOY 19 ELK
5 58 73079535121503 393110755253
5 57 12-71 BUOY C7 ELK
5 58 73079535215408 393250755148
5 57 13-71 BUOY N16 ELK
5 58 73079535410083 393408755103
5 59 082768 082471 003 1 028
5 62 MARTHE COLE-JONES A
```

```
                   ******  M022010 ******
1  2 M022010
1  4 C BIO LAB
1  7 POLLUTION SURVEY OF THE PATAPSCO RIVER, BALTIMORE HARBOR
1  7         1938-1939  ROBERT A. LITTLEFORD
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY,PATAPSCO RIVER
1 17 PH    - BECKMAN PH METER OR LAMOTTE INDICATORS
1 17 D.O.  - WINKLER MODIFIED
1 17 PO4   - NEWCOMBE 1939
1 17 TOTAL IRON   - THOMPSON,T.G. & R.W. BREMNER 1935  "THE DETERMINATION
1 17        OF IRON IN SEA WATER" J.DU. CONSEIL. 10:33-38
1 17    ALSO STANDARD METHODS OF WATER ANALYSES OF THE AMERICAN PUBLIC
1 17                  HEALTH ASSOC. 1936
1 17 TEMPERATURE   - DATA IS SKETCHY. OCCASIONAL NOTES OF "THERMOMETER
1 17       OUT OF ORDER" AND UNUSUALLY HIGH VALUES RESULT IN CODE
1 17       MODIFICATION "K"
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   400  PH (STANDARD UNITS)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   669   PHOSPHORUS,TOTAL HYDROLYZABLE (MG/L AS P)
1 17 74010  IRON, TOTAL ( MG/L AS FE)
1 18 DONALD R. HEINLE
1 19 301 326-4281
1 20 CHESAPEAKE BIOLOGICAL LABORATORY
1 21 P.O. BOX 38
1 22 SOLOMONS
1 23 MARYLAND
1 25 20688
1 27 9 STATIONS SAMPLED ONCE OR TWICE A MONTH FOR 20 MONTHS FOR
1 27 TEMPERATURE, PH, DISSOLVED OXYGEN, AND SALINITY
1 27 SOME ADDITIONAL STATIONS AND PARAMETERS SAMPLED WITH LESS FREQUENCY
5 38 1                      537
5 39 1                       94
5 45 1                      482
5 46 1                      464
5 48 1                      509
5 53 1 TOTAL IRON           141
5 54 1 SECCHI                37
5 57 1-38 FORT CARROLL
5 58 73079613310400 391300763140
5 57 IA-38 LEADING PT
5 58 73079613320485 391308763245
5 57 II-38 SLEDDS PT
5 58 73079613340005 391300763405
5 57 III-38 FIREBOAT DOCK
5 58 73079613340380 391308763430
5 57 IV-38 STONEHOUSE COVE
5 58 73079613343505 391330763455
5 57 V-38 OFF CABIN BRANCH
5 58 73079613244450 381245763440
5 57 VI-38 CABIN BRANCH
5 58 73079613255050 391255763500
5 57 VII-38 HIGHWAY BRIDGE
```

```
5 58 73079613242552 391225763452
5 57 VIII-38 RAILROAD BRIDGE
5 58 73079613145355 391155763435
5 57 X-38 FURNACE/MARLEY CREEK
5 58 73079613141403 391110763443
5 57 XA-38 MARLEY CREEK
5 58 73079613150405 391100763545
5 57 IXA-38 FURNACE CREEK
5 58 73079613150155 391105763515
5 57 XI-38 INSIDE SLEDDS PT
5 58 73079613244285 391248763425
5 57 XII-38 OFF DUPONT SEWER
5 58 73079613341480 391318763440
5 57 XIII-38 SOLLERS PT
5 58 73079613313570 391337763150
5 57 XIV-38 BEAR CREEK
5 58 73079612394585 391348762955
5 57 SANDY POINT
5 58 73079602033000 390030762300
5 57 SEVEN FT KNOLL
5 58 73079602941451 390915762441
5 57 COLGATE CREEK
5 58 73079613520185 391508763215
5 57 WESTERN MD RR
5 58 73079613575330 391553763730
5 59 012038 080239 002 3 010
5 60 DON HEINLE          A
5 62 MARTHE COLE-JONES A
```

```
                    ******  M022011 ******
1  2 M022011
1  4 MD DEPT NAT RES
1  7 ELK RIVER - C&D CANAL; PHYSICAL, CHEMICAL, AND BACTERIOLOGICAL
1  7   WATER QUALITY REPORT NO 1   OCT 1967 - JULY 1968
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, ELK RIVER AND CHESAPEAKE AND
1 14        DELAWARE CANAL
1 17 D.O. WAS MEASURED WITH A YSI MODEL SY BP OXYGEN METER
1 17 WATER TEMP, CONDUCTIVITY, AND SALINITY WERE MEASURED WITH
1 17 AN INDUSTRIAL INSTRUMENT RS5 SALINOMETER.
1 17 PH WAS MEASURED WITH A SARGENT PH METER, MODEL PB
1 17 AIR TEMP WAS DETERMINED IN THE SHADE WITH A FISCHER SCI THERMOMETER
1 17 SURFACE BACTERIOLOGICAL SAMPLES WERE TAKEN IN STERILIZED 125 ML SCREW-CAP
1 17 BOTTLES. BOTTOM SAMPLES WERE TAKEN USING STERILE EVACUATED 100ML AMPULES
1 17 IN A HYTECH STERILE WATER SAMPLER.  SAMPLES WERE ANALYZED FOR COLIFORM
1 17 BACTERIA AND FOR E.COLI AT THE ELKTON LABORATORY OF THE STATE
1 17     DEPT OF HEALTH.  COUNTS ARE GIVEN AS MOST-PROBABLE-NUMBER PER 100ML
1 17 WEATHER AND TIDE DATA ARE GIVEN IN THE REPORT, BUT DATA NOT ENCODED
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    20  TEMPERATURE, AIR (DEGREES CENTIGRADE)
1 17   400  PH (STANDARD UNITS)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   299  OXYGEN, DISSOLVED, ( ELECTRODE ) ( MG/L )
1 17 31614  FECAL COLIFORM, MPN, TUBE CONFIGURATION
1 17 98760  COLIFORM, TOTAL, MPN, TUBE CONFIGURATION
1 17 98762  CONDUCTIVITY AT AMBIENT TEMP (MICROMHOS)
1 27 EIGHT STATIONS SAMPLED ON THREE SEPARATE DATES FOR SEVEN PARAMETERS:
1 27   D.O., PH, E.COLI, COLIFORMS, TEMP, SALINITY, AND CONDUCTIVITY
5 38 1                     34
5 44 1                     40
5 45 1                     57
5 46 1                     56
5 48 1                     34
5 53 1 FECAL COLIFORMS     40
5 54 1 AIR TEMP            24
5 55 1 CONDUCTIVITY        56
5 57 EI
5 58 73079525693466 392636755948
5 57 E2
5 58 73079525880204 392800755824
5 57 E3
5 58 73079525960468 392906755648
5 57 E4
5 58 73079535043040 393034755400
5 57 E5
5 58 73079535214535 393243755155
5 57 E6
5 58 73079535403338 393433755038
5 57 CD1
5 58 73079535122340 393124755230
5 57 CD2
5 58 73079534184522 393142754852
5 59 103167 070968 001 3 008
5 60 DON HEINLE          A
5 62 BUD MILLSAPS       A
```

```
                              ****** M022012 ******
1  2 M022012
1  4 MD DEPT NAT RES
1  7 COLIFORM AND E. COLI BACTERIA COUNTS AT A MAJOR CHESAPEAKE BAY
1  7 BOATING - BATHING SITE DURING THE INDEPENDENCE DAY HOLIDAY PERIOD
1 14 NORTH AMERICA, US, COASTAL, MARYLAND, CHESAPEAKE BAY, SOUTH RIVER
1 17 WATER TEMP AND SALINITY WERE DETERMINED USING AN  INDUSTRIAL
1 17          INSTRUMENTS INDUCTION-TYPE SALINOMETER
1 17 PH WAS MEASURED WITH A BECKMAN MODEL "N" PH METER.
1 17 DISSOLVED OXYGEN WAS DETERMINED BY THE ALSTERBURG AZIDE MODIFICATION
1 17            OF THE WINKLER METHOD
1 17 COLIFORM AND E COLI WERE DETRRMINED BY THE THREE-TUBE DILUTION
1 17           METHOD OND REPORTED AS MOT-PROBABLE-NUMBER PER 100ML.
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17   400  PH (STANDARD UNITS)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17 31614  FECAL COLIFORM, MPN, TUBE CONFIGURATION
1 17 98760  COLIFORM, TOTAL, MPN, TUBE CONFIGURATION
1 27 FIVE PARAMETERS (D.O., TEMP, SALINITY, COLIFORM, AND FECAL COLIFORM)
1 27        SAMPLED ON SIX DIFFERENT DATES AT SEVEN STATIONS
1 27 223 RECORDS
5 38 1                    90
5 44 1                    90
5 45 1                    89
5 46 1                    90
5 48 1                    90
5 53 FECAL COLIFORM       89
5 57 1 MOUTH SELBY BAY
5 58 73078653402144 385424763014
5 57 2 SELBY BAY
5 58 73078653403428 385432763048
5 57 3 SELBY BAY
5 58 73078653402379 385427763039
5 57 4 SELBY BAY
5 58 73078653401375 385417763035
5 57 5 SELBY BAY
5 58 73078653401317 385411763037
5 57 6 MOUTH RAMSEY LAKE
5 58 73078653400278 385407763028
5 57 7 SELBY BAY
5 58 73078653401210 385411763020
5 59 070264 070764 001 5 007
5 60 DONALD HEINLE        A
5 62 BUD MILLSAPS         A
```

```
****** M022013 ******
1  2 M022013
1  4 MD DEPT NAT RES
1  7 WATER QUALITY FROM SELECTED STATIONS IN CHESAPEAKE BAY AND THE
1  7 POTOMAC RIVER 1967
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, POTOMAC RIVER AND CHESAPEAKE BAY
1 17 METHODS - 24 HR SAMPLING
1 17           VERTICAL SAMPLING SURFACE TO 40FT AT 5 FT INTERVALS EVERY 2 HRS
1 17 SCHNEIDER INSTRUMENT CO. WATER QUALITY ROBOT MONITOR WAS USED FOR
1 17           SAMPLING AND RECORDING
1 17 D.O. CHECKED AGAINST TITRATED SAMPLE USING AZIDE MODIFICATION OF WINKLER
1 17 SAMPLED ON 5 SEPARATE DATES. ONCE PER MO 3 TIMES,2TIMES PER MO 1 TIME
1 18 CARLO R. BRUNORI
1 20 WATER RESOURCES ADMINISTRATION, DEPT. NATURAL RESOURCES
1 21 TAWES STATE OFFICE BUILDING
1 22 ANAPOLIS
1 23 MARYLAND
1 24 USA
1 25 21401
1 27 3 STATIONS FIVE TIMES ON 24 HR BASIS FOR D.O., TEMP, CONDUCTIVITY,
1 27 AND PH AT 0 TO 40FT, 5FT INTERVALS
5 38 1
5 45 1
5 48 1
5 53 1 CONDUCTIVITY
5 57 FK14 FISH KILL #14
5 58 73078652915200 385950762120
5 57 F1 FLAGPOND #1
5 58 73078622641435 382613762445
5 57 M7 MORGANTOWN #1
5 58 73078625193030 382133765900
5 59 062967 110167       003
5 62 MARTHE COLE-JONES  U
5 63 DATA PRESENTED AS MAXIMUM/MINIMUM VALUES OR AS GRAPHS ONLY.
5 63 GRAPHS COVER VERTICAL DEPTH SAMPLING FOR EACH HOUR TESTED
```

```
                     ******  M022014 ******
 1  2 M22014
 1  4 MD DEPT NAT RES
 1  7 FISH KILL INVESTIGATIONS ST MICHAELS HARBOR, OAK CREEK, MILES RIVER ESTUARY
 1  7 PHYSICAL, CHEMICAL AND BACTERIOLOGICAL WATER QUALITY, SUMMER 1969 TO
 1  7   OCT 1970
 1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, MILES RIVER
 1 17 METHODS: CONDUCTIVITY, SALINITY & TEMP: INDUSTRIAL INSTRUMENT
 1 17          RS 5-3 SALINOMETER
 1 17 D.O. YSI MODEL 54 OXYGEN METER
 1 17 PH  ORION SPECIFIC ION MODEL 401 METER
 1 17 ALL CHEMICAL ANALYSES: STANDARD METHODS FOR THE EXAMINATION OF
 1 17 WATER & WASTEWATER.  1965  12TH EDITION
 1 17 ASSUMPTION MADE THAT FECAL COLIFORM TEST UTILIZED E.C. MEDIUM AT 44.5 C, 24
 1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
 1 17   299  OXYGEN, DISSOLVED (ELECTRODE)(MG/L)
 1 17   310  BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
 1 17   400  PH (STANDARD UNITS)
 1 17   480  SALINITY - PARTS PER THOUSAND
 1 17   630  NITRITE PLUS NITRATE, TOTAL, 1 DET. (MG/L AS N )
 1 17   660  PHOSPHATE, ORTHO (MG/L AS PO4)
 1 17 31615  FECAL COLIFORM, MPN, EC MED, 44.5C,(TUBE31614)(MPN/100ML)
 1 17 32209  CHLOROPHYLL A UG/L FLUOROMETRIC CORRECTED
 1 17 71886  PHOSPHORUS, TOTAL, AS PO4 (MG/L)
 1 17 98760  COLIFORM, TOTAL, MPN, TUBE CONFIGURATION
 1 17 98762  CONDUCTIVITY AT AMBIENT TEMP (MICROMHOS)
 1 18 CARLO R. BRUNORI
 1 20 MARYLAND DEPT NATURAL RESOURCES
 1 21 TAWES STATE OFFICE BUILDING
 1 22 ANNAPOLIS
 1 23 MARYLAND
 1 25 21401
 1 27 12 PARAMETERS MEASURED 1 TIME/ MO FOR 8 MOS AT 20 STATIONS
 5 35 1 CHL A             189
 5 38 1
 5 39 1 TOTAL & ORTHO     405
 5 40 1 NO2 & NO3         216
 5 44 1                    18
 5 45 1                   216
 5 46 1                   216
 5 48 1
 5 49 1
 5 53 1   CONDUCTIVITY    216
 5 54 1 FECAL COLIFORMS    18
 5 57 A-1 OAK CREEK
 5 58 73078641404276 384447761026
 5 57 A-2 OAK CREEK
 5 58 73078641404256 384445761026
 5 57 A-3 OAK CREEK
 5 58 73078641404236 384443761026
 5 57 B-1 OAK CREEK
 5 58 73078641405275 384457761025
 5 57 B-2 OAK CREEK
 5 58 73078641405268 384456761028
 5 57 B-3 OAK CREEK
```

```
5 58 73078641405351 384455761031
5 57 C-1 OAK CREEK
5 58 73078641500280 384508761020
5 57 C-2 OAK CREEK
5 58 73078641500285 384508761025
5 57 C-3 OAK CREEK
5 58 73078641500390 384509761030
5 57 E-1 MILES RIVER
5 58 73078641730077 384707761307
5 57 E-2 MILES RIVER
5 58 73078641731007 384710761307
5 57 E-3 MILES RIVER
5 58 73078641731037 384713761307
5 57 F-1 MILES RIVER
5 58 73078641730185 384708761315
5 57 F-2 MILES RIVER
5 58 73078641731155 384715761315
5 57 F-3 MILES RIVER
5 58 73078641732105 384720761315
5 57 G-1 MILES RIVER
5 58 73078641731020 384712761300
5 57 G-2 MILES RIVER
5 58 73078641731081 384718761301
5 57 G-3 MILES RIVER
5 58 73078641732023 384722761303
5 57 NUN BUOY N-4
5 58 73078641724203 384740761223
5 57 7 FLASHING LIGHT BUOY
5 58 73078641505208 384550761028
5 59 091669 100670 001 3 020
5 60 DON HEINLE          A
5 62 MARTHE COLE-JONES A
```

```
                        ****** M022015 ******
1  2 M022015
1  4 US EPA REG 3
1  7 BIOL SURVEY OF THE UPPER POTOMAC RIVER AND SELECTED TRIBS 1966-68
1  7 DATA REPORT #4
1 14 NO AMERICA, US, MD, COASTAL, POTOMAC RIVER:NO BRANCH, SO BRANCH& MAIN STEM
1 17 UP-STREAM SAMPLING FROM GREAT FALLS USING BOTTOM MACRO-ORGANISMS
1 17 AS INDICATORS OF BIOLOGICAL CONDITIONS CLASSED AS POLLUTION-
1 17 SENSITIVE, INTERMEDIATE AND POLLUTION-TOLERANT
1 17 METHODS: STATIONS SAMPLED ONCE AND KINDS OF MACRO BOTTOM ORGANISMS
1 17 TENTATIVELY IDENTIFIED .  IF POSSIBLE, A QUALITITIVE AND QUANTITATIVE
1 17 SAMPLE WAS TAKEN QUANTITATIVE BOTTOM SAMPLES TAKEN USING A  SURBER
1 17 SQUARE FOOT SAMPLER, AN EKMAN DREDGE (0.5 SQ FT) OR A PETERSON DREDGE
1 17 (0.6 SQ FT).  SAMPLES SCREENED WITH NO. 30 US STANDARD SEIVE
1 17 SERIES. ANIMALS PRESERVED IN 10% FORMALIN
1 17 QUANTITATIVE: RESULTS EXPRESSED AS # OF ORGANISMS PER SQ FT RIVER BOTTOM
1 17 QUALITATIVE: # OF KINDS OF ORGANISMS PER SAMPLE
1 17 92 STATIONS IN NORTH BRANCH OF POTOMAC, UPPER POTOMAC AND KEY TRIBUTARIES
1 17 REPORT IS SUPPLEMENT TO "INTERIM REPORT - MINE DRAINAGE POLLUTION OF
1 17 NORTH BRANCH OF POTOMAC RIVER 1966-68."     "WATER QUALITY IN THE
1 17 NORTH BRANCH OF POTOMAC RIVER BETWEEN CUMBERLAND AND LAKE MARYLAND."
1 18 JAMES L. LABUY
1 20 FEDERAL WATER QUALITY ADMINISTRATION (EPA), MIDDLE ATLANTIC REGION
1 21 918 EMMET STREET
1 22 CHARLOTTESVILLE
1 23 VIRGINIA
1 25 22901
1 27 92 STATINS IN POTOMAC RIVER AND TRIBUTARIES SAMPLED OVER 2 YEAR PERIOD
1 27 FOR BOTTOM MACRO-ORGANISMS
5 62 MARTHE COLE-JONES  U
5 63 NO WATER QUALITY DATA AS SUCH; REPORT DEALS WITH QUALITATIVE AND
5 63 QUANTITATIVE MEASUREMENTS OF MARCO-BENTHOS AS INDICATOR ORGANISMS
5 63 OF POLLUTION
```

```
                     ****** M022016 ******
1  2 M02016
1  4 EPA REGION III
1  7 UPPER POTOMAC ESTUARY EUTROPHICATION CONTROL REQUIREMENTS
1  7 TECHNICAL REPORT #53  APRIL 1972
1 14 NORTH AMERICA, U.S.,.MARYLAND, COASTAL POTOMAC RIVER
1 17 REPORT IS SUMMARY OF NUMEROUS REPORTS PUBLISHED BY AFD/EPA SINCE
1 17 1965 (FORMERLY FEDERAL WATER QUALITY ADMINISTRATION)
1 17 PRESENT REPORT IS DESCRIPTIVE OF WATER QUALITY PROBLEMS IN POTOMAC
1 17 RIVER;  DATA PRESENTED AS NUTRIENT LOADINGS IN KG/DAY.
1 18 NORB JAWORSKI, LEO CLARK, KENNETH P. FEIGNER
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 24 USA
1 25 21401
5 60 MARTHE COLE-JONES   U
5 61 DESCRIPTIVE SUMMARY OF VARIOUS REPORTS  DATA PRESENTED GRAPHICALLY
5 61 AND AS NUTRIENT LOADINGS  KG/DAY.
5 64   1
```

```
                    ****** M022017 ******
1  2 M022017
1  4 MD DEPT NAT RES
1  7 PHOSPHATE DETERMINATIONS - CHESAPEAKE SHELLFISH INVESTIGATIONS
1  7      1952  JIM ENGLE
1 10 MARYLAND OYSTER BAR SURVEYS
1 14 NORTH AMERICA, U.S.,MARYLAND,COASTAL, CHES BAY
1 17 DISSOLVED PHOSPHATE WAS DETERMINED BY THE STANNOUS CHLORIDE
1 17    METHOD.  SAMPLES WERE READ IN SPECTROPHOTOMETER AT 700 MU
1 17   671  PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
1 20 MARYLAND DEPT OF NATURAL RESOURCES
1 21 TAWES STATE OFFICE BUILDING
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 5 STATIONS SAMPLED  1 TO 3 TIMES PER MO FOR 2 YRS FOR DISSOLVED PHOSPHATE
5 39 1                    500
5 57 HACKETTS
5 58 73078652854320 385842762530
5 57 TOLLYS
5 58 73078652664320 385642762630
5 57 LONG PT
5 58 73078652005040 385054762000
5 57 BODKIN
5 58 73078651370402 385300761742
5 57 MILL HILL
5 58 73078651431128 385412761318
5 59 061652 090754 001 3 005
5 60 DONALD R. HEINLE   A
5 62 H.S. MILLSAPS     A
```

```
                              ******  M022018 ******
 1  2 M022018
 1  4 VA VIMS
 1  7 A BIOLOGICAL AND CHEMICAL STUDY OF THE TIDAL JAMES RIVER.
 1  7 1966 VIMS REPORT BY M.L. BREHMER & S.O. HALTIWANGER
 1 14 NORTH AMERICA, U.S., VIRGINIA, COASTAL, JAMES RIVER
 1 17 ANALYTICAL METHODS FOR CHEMISTRY NOT DESCRIBED; ASSUMED TO BE
 1 17 STRICKLAND AND PARSONS AND STANDARD METHODS.
 1 17    10 TEMPERATURE, WATER (DEGREES CENTIGRADE)
 1 17    78 TRANSPARENCY, SECCHI DISC (METERS)
 1 17   410 ALKALINITY, TOTAL (MG/L AS CACO3)
 1 17   480 SALINITY - PARTS PER THOUSAND
 1 17   400 PH (STANDARD UNITS)
 1 17   613 NITRITE NITROGEN,DISSOLVED (MG/L)
 1 17   618 NITRATE NITROGEN, DISSOLVED (MG/LAS N)
 1 17   665 PHOSPHORUS, TOTAL (MG/L AS P)
 1 17   671 PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
 1 17   673 PHOSPHORUS, DISSOLVED ORGANIC (MG/L AS P)
 1 17 32209 CHLOROPHYLL A UG/L FLUOROMETRIC CORRECTED
 1 17 71100 SEDIMENT, SUSPENDED PARTICULATE (MG/L)
 1 17 98755 PHOSPHORUS, PARTICULATE UNREACTIVE (UG AT/L)
 1 17 98756 PHOSPHORUS, PARTICULATE REACTIVE (UG AT/L)
 1 17 98757 LOSS ON IGNITION (OF SUSPENDED SEDIMENT) (MG/L)
 1 17 98758 NITROGEN PARTICULATE, ORGANIC (UG AT/L)
 1 18 LIBRARIAN
 1 20 VIRGINIA INSTITUTE OF MARINE SCIENCE
 1 22 GLOUCESTER POINT
 1 23 VIRGINIA
 1 24 USA
 1 25 23062
 1 27 TEN STATIONS SAMPLED ONE TIME PER MO FOR ONE YR FOR 12 PARAMETERS
 5 35 1 CHL A              240
 5 37 1 SECCHI             115
 5 38 1                    611
 5 39 1 TP SRP SUP         720
 5 40 1 OPN NO2 NO3        672
 5 43 1 SESTON             240
 5 52 1                    240
 5 53 1 FREE RESIDUE
 5 57 J-4 HAMPTON ROADS
 5 58 73076652004000 365040762000
 5 57 J-10 NEWPORT NEWS
 5 58 73077602000505 370000762055
 5 57 J-17 MULLBERRY ISL
 5 58 73077603002305 370020763035
 5 57 J-22 MULLBERRY POINT
 5 58 73077603004457 370045763047
 5 57 J-29 HOG POINT
 5 58 73077614001050 371015764000
 5 57 J-36 SWAN POINT
 5 58 73077614001467 371016764047
 5 57 J-47 BRANDON POINT
 5 58 73077615004500 371040765050
 5 57 J-57 WINDMILL POINT
 5 58 73077710005320 371052770030
```

```
5 57 J-68 EPPES ISLAND
5 58 73077721000302 372000771032
5 57 J-67 KINGSLAND CK
5 58 73077722002157 372025772017
5 59 050665 051166 001 3 010
5 62 MARTHE COLE-JONES A
```

```
                    ****** M022019 ******
1  2 M022019
1  4 C BIO LAB
1  7 LITTLE COVE POINT BAY OXYGEN PROGRAM 1958-1965
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY
1 17     10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17     77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17    295  OXYGEN, DISSOLVED (ML/L)
1 17    400  PH (STANDARD UNITS)
1 17    480  SALINITY - PARTS PER THOUSAND
1 17 THIS WATER QUALITY DATA WAS TAKEN AS PART OF AN INVESTIGATION
1 17 INTO THE CAUSES OF SUMMER CRAB MORTALITY.  TEMPERATURE WAS DETERMINED WITH
1 17 AN ELECTRONIC PROBE.  SALINITY WAS DETERMINED WITH A HYDROMETER.
1 17 PH WAS DETERMINED BY A COLORAMETRIC  METHOD.  D.O. WAS DETERMINED BY A
1 17 TITRAMETRIC METHOD AND EXPRESSED AS ML OXYGEN PER LITER.
1 17 1958 - 5 STAS;  1959 - 1 STA;  1960,61 - 2 STAS;  1964 - 4 STAS
1 17 1965 - 1 STA;  1962 AND 1963: DATA CURRENTLY MISSING AND MAY BE
1 17 AT HORN POINT WITH CRAB DATA.  CONTACT BOB MILLER:  HORN POINT
1 17 ENVIRONMENTAL LABORATORY, BOX 775, CAMBRIDGE, MD. 21613
1 17 SAMPLING DATES : FOR 4 MONTHS OUT OF YEAR, VARIABLE
1 17 1-5 STATIONS PER SEASON
1 17     10 TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17     77 TRANSPARENCY, SECCHI DISC (INCHES)
1 17    295 OXYGEN, DISSOLVED (ML/L)
1 17    480 SALINITY - PARTS PER THOUSAND
1 19 301 326-4281
1 20 UNIVERSITY OF MARYLAND, CHESAPEAKE BIOLOGICAL LABORATORY
1 21 P.O. BOX 38
1 22 SOLOMONS
1 23 MARYLAND
1 24 USA
1 25 20688
1 17 ONE TO FIVE STATIONS SAMPLED FOR FOUR
1 27 PARAMETERS ON THE AVERAGE OF 2 TO 3 TIMES PER WEEK FROM JUNE TO SEPT
1 27 FOR 8 YRS (2 YEARS MISSING)
5 38 1                   1088
5 45 1                   1535
5 46 1                   1494
5 48 1                   1351
5 54 1             SECCHI  204
5 57 LONG BEACH STA  1
5 58 73078622875343 382854762733
5 57 LONG BEACH STA  2
5 58 73078622885542 382854762852
5 57 LONG BEACH STA  3
5 58 73078622880166 382806762816
5 57 LONG BEACH STA  4
5 58 73078622785168 382756762818
5 57 LITTLE COVE PT BAY
5 58 73078622110308 382100762138
5 57 LITTLE COVE PT 20 FT
5 58 73078622110532 382103762152
5 57 BUOY 16E
5 58 73078621183486 382138761846
5 57 BUOY 16E SHALLOW
```

```
5 58 73078621183388 382138761838
5 59 081450 091765 002 4 008
5 60 DONALD R. HEINLE   A
5 62 H.S. MILLSAPS     A
```

```
                          ****** M022020 ******
1  2 M022020
1  4 PA ACAD NS PHIL
1  7 POTOMAC RIVER (MORGANTOWN) RIVER SURVEY REPORTS 1966,1968,1972,1973
1  7 CHEMICAL, BACTERIOLOIGCAL AND PHYSICAL WATER QUALITY STUDIES
1  7 1969 THRU 1974
1 10 POTOMAC RIVER SURVEY
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, POTOMAC RIVER
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    78  TRANSPARENCY, SECCHI DISC (METERS)
1 17    95  CONDUCTIVITY AT 25 DEGREES C (MIRCOMHOS)
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   310  BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
1 17   400  PH (STANDARD UNITS)
1 17   410  ALKALINITY, TOTAL (MG/L AS CACO3)
1 17   415  ALKALINITY, PHENOLPHTALEIN (MG/L AS CACO3)
1 17   425  ALKALINITY, BICARBONATE (MG/L AS CACO3)
1 17   440  BICARBONATE ION (MG/L AS HCO3)
1 17   445  CARBONATE ION (MG/L AS CO3)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   500  RESIDUE (SOLIDS) TOTAL (MG/L)
1 17   505  RESIDUE, TOTAL, VOLATILE (MG/L)
1 17   510  RESIDUE, TOTAL FIXED (MG/L)
1 17   608  NITROGEN, AMMONIA, DISSOLVED (MG/L AS N)
1 17   610  NITROGEN, AMMONIA, TOTAL  (MG/L AS N)
1 17   613  NITRITE NITROGEN, DISSOLVED (MG/L AS N)
1 17   618  NITRATE NITROGEN, DISSOLVED (MG/L AS N)
1 17   625  NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   650  PHOSPHATE, TOTAL (MG/L AS PO4)
1 17   671  PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
1 17   940  CHLORIDE (MG/L AS CL)
1 17   946  SULFATE, DISSOLVED (MG/L AS SO4)
1 17   955  SILICA,DISSOLVED (MG/L AS SIO2)
1 17 31501  COLIFORM, TOTAL,MEMERANE FILTER IMMED. M-ENDO MED 35C (#/100ML)
1 17 31751  PLATE COUNT, TOTAL, TPC AGAR 35 C/24HR (#/1ML)
1 17 70507  PHOSPHORUS, IN TOTAL ORTHOPHOSPHATE (MG/L AS P)
1 17 98754  TURBIDITY, PHOTOMETRIC 420 MU (MG/L)
1 18 DR. RUTH PARTICK
1 19 215-299-1114
1 20 ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA/DEPT OF L1MN
1 21 19TH AND THE PARKWAY
1 22 PHILADELPHIA
1 23 PENNSYLVANIA
1 25 19103
1 27 (SURVEYS) 3 STATIONS SURFACE/BOTTOM 1 X/MO  11-12 MOS/5 YRS
1 27 (WQ) 3-4 STATIONS SAMPLED AT 4-5 HI & LO TIDES AT EARLY
1 27 AND LATE SUMMER SEASON FOR 4 YEARS
5 37 1
5 38 1
5 39 1
5 40 1
5 41 1
5 44 1
5 45 1
```

```
5 46 1
5 47 1
5 48 1
5 49 1
5 53 1 SECCHI
5 54 1 SPECIFIC COND
5 55 1 BICARBONATE ION     210
5 55 1 CARBONATE ION       150
5 55 1 FECAL COLIFORM       32
5 55 1 TOTAL SOLIDS        131
5 55 1 VOLITALE SOLIDS     130
5 55 1 FIXED SOLIDS        130
5 55 1 TOTAL PLATE COUNT  314
5 57 1-66 POPES CREEK
5 58 73078625392578 382327765958
5 57 2-66 301 BRIDGE
5 58 73078625194205 382140765925
5 57 3-66 MORGANTOWN/CEDAR POINT
5 58 73078625082155 382025765815
5 57 1-69 POPES CREEK
5 58 73078720400350 382405770030
5 57 2-69 PLANT SITE
5 58 73078625192484 382128765944
5 57 3-69 MORGANTOWN
5 58 73078615995009 381950765909
5 57 MATHIAS POINT #4
5 58 73078720424140 382444770210
5 57 1-TRANSECT POPES CREEK
5 58 73078625394585 382348765955
5 57 2-TRANSECT POPES CREEK
5 58 73078720304124 382342770014
5 57 3-TRANSECT POPES CREEK
5 58 73078720303323 382332770033
5 57 4-TRANSECT POPES CREEK
5 58 73078720302530 382323770050
5 57 5-TRANSECT POPES CREEK
5 58 73078720311161 382316770111
5 57 BUOY N
5 58 73078720401334 382413770034
5 57 BUOY S
5 58 73078625295169 382256765919
5 57 BOD-1 POPES CREEK
5 58 73078625392578 382327765958
5 57 BOD-2 MORGANTOWN
5 58 73078625085305 382050765835
5 57 DO STATION 1-A
5 58 73078625393520 382332765950
5 57 DO STATION 1-B
5 58 73078720302108 382320770018
5 57 DO STATION 1-C
5 58 73078720300495 382309770045
5 57 DO STATION 2-A
5 58 73078625193293 382139765923
5 57 DO STATION 2-B
5 58 73078625193546 382134765956
```

```
5 57 DO STATION 2-C
5 58 73078720103208 382130770028
5 57 DO STATION 3-A
5 58 73078625082427 382022765847
5 57 DO STATION 3-B
5 58 73078625091258 382015765928
5 57 DO STATION 3-C
5 58 73078720001100 382010770010
5 57 DO TRANSECT 1-1
5 58 73078625394585 382348765955
5 57 DO TRANSECT 1-2
5 58 73078720304124 382342770014
5 57 DO TRANSECT 1-3
5 58 73078720303323 382332770033
5 57 DO TRANSECT 1-4
5 58 73078720302530 382323770050
5 57 DO TRANSECT 1-5
5 58 73078720311161 382316770111
5 57 DO TRANSECT 2-1
5 58 73078625194115 382141765915
5 57 DO TRANSECT 2-2
5 58 73078625193385 382138765935
5 57 DO TRANSECT 2-3
5 58 73078625193555 382135765955
5 57 DO TRANSECT 2-4
5 58 73078720103135 382133770015
5 57 DO TRANSECT 2-5
5 58 73078720103305 382130770035
5 57 DO TRANSECT 3-1
5 58 73078625082334 382023765834
5 57 DO TRANSECT 3-2
5 58 73078625091082 382018765902
5 57 DO TRANSECT 3-3
5 58 73078625091350 382015765930
5 57 DO TRANSECT 3-4
5 58 73078625091526 382012765956
5 57 DO TRANSECT 3-5
5 58 73078720000275 382007770025
5 59 082466 121274  001  3 000
5 60 DAVE MORCK        A
5 62 MARTHE COLE-JONES A
```

```
                         ****** M022021 ******
1  2 M022021
1  4 PA ACAD NS PHIL
1  7 A CHEMICAL, BACTERIOLOGICAL AND PHYSICAL STUDY ON THE CHESAPEAKE
1  7    BAY IN THE VICINITY OF CALVERT CLIFFS  1968,69,70,71,72,73,75
1  7 FOR BALTIMORE GAS AND ELECTRIC COMPANY (BG&E)
1 10 CALVERT CLIFFS BASELINE STUDY FOR BG&E
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    70  TURBIDITY, ( JACKSON CANDLE UNITS )
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   310  BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
1 17   400  PH (STANDARD UNITS)
1 17   410  ALKALINITY, TOTAL (MG/L AS CACO3)
1 17   415  ALKALINITY, PHENOLPHTALEIN (MG/L AS CACO3)
1 17   440  BICARBONATE ION (MG/L AS HCO3)
1 17   445  CARBONATE ION (MG/L AS CO3)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   608  NITROGEN, AMMONIA, DISSOLVED (MG/L AS N)
1 17   610  NITROGEN, AMMONIA, TOTAL  (MG/L AS N)
1 17   613  NITRITE NITROGEN, DISSOLVED (MG/L AS N)
1 17   615  NITRITE NITROGEN, TOTAL (MG/L AS N)
1 17   618  NITRATE NITROGEN, DISSOLVED (MG/L AS N)
1 17   625  NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   650  PHOSPHATE, TOTAL (MG/L AS PO4)
1 17   665  PHOSPHORUS, TOTAL (MG/L AS P)
1 17   671  PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
1 17   940  CHLORIDE (MG/L AS CL)
1 17   946  SULFATE, DISSOLVED ( MG/L AS SO4)
1 17   955  SILICA, DISSOLVED (MG/L AS SIO2)
1 17   956  SILICA, TOTAL (MG/L AS SIO2)
1 17 31501  COLIFORM, TOTAL, MEMBRANE FILTER IMMED. M-ENDO MED 35C (#/100ML)
1 17 31616  FECAL COLIFORM, MEMB. FILTER, M-FC BROTH 44.5 C (#/100ML)
1 17 31751  PLATE COUNT, TOTAL, TPC AGAR 35 C/24HR (#/1 ML)
1 17 70507  PHOSPHORUS, IN TOTAL ORTHOPHOSPHATE (MG/L AS P)
1 17 98753  ALKALINITY, METHYL PURPLE ( MG/L AS CACO3)
1 17 98754  TURBIDITY, PHOTOMETRIC 420 MU (MG/L)
1 17 STANDARD METHODS 12TH ED FOR 1968,69,70
1 17 STANDARD METHODS 13TH ED FOR 1971,72,73
1 17 MURPHY & RILEY (1962) FOR TP
1 17 SURFACE: 1968 (JUNE,AUG,SEPT,DEC) (4 STATIONS)
1 17 SURFACE: 1969 (JAN,JULY,AUG,SEPT,OCT,NOV,DEC) (5 STATIONS)
1 17 SURFACE AND BOTTOM: 1970 (ALL MOS EXCEPT JAN)
1 17 SURFACE AND BOTTOM: 1971  (12 MOS, 5 STATIONS)
1 17 SURFACE AND BOTTOM 1972 ( 12 MOS, 5 STATIONS)
1 17 SURFACE AND BOTTOM 1973 (12 MOS, 5 STATIONS)
1 17 SURFACE AND BOTTOM 1975 (6 MOS, 4 STATIONS)
1 17 1975 MEASUREMENTS WERE DONE IN REP[LICATE
1 17 ADDITIONAL PARAMETERS MEASURED OR CALCULATED BUT NOT ENCODED INCLUDE:
1 17 BORON, IRON, MANGANESE, COPPER, NICKEL, ZINC, CHROMIUM, SODIUM,
1 17 POTASSIUM, MAGNESIUM, TOTAL HARDNESS, CALCIUM HARDNESS, MAGNESIUM
1 17 HARDNESS, CALCIUM AND CARBON DIOXIDE
1 18 DR. CLYDE GOULDEN
1 20 THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA/DEPT LIMN.
1 21 19TH AND THE PARKWAY
```

```
1 22 PHILADELPHIA
1 23 PENNSYLVANIA
1 25 19103
1 27 5 STATIONS (4 IN 1968) SAMPLED APPROX 1 X / MO FOR APROX 12 MO/YR FOR 7 YRS
5 37 1                    576
5 38 1                    645
5 39 1                   1470
5 40 1                   2151
5 41 1                    603
5 44 1                    364
5 45 1                    645
5 46 1                    645
5 47 1                   1622
5 48 1                    642
5 49 1                   1186
5 53 1 BICARBONATE ION    179
5 54 1 CARBONATE ION      282
5 55 TOTAL PLATE COUNT    272
5 57 KENWOOD BEACH
5 58 73078632080407 383000762847
5 57 LONG BEACH
5 58 73078622851353 382815762533
5 57 PLANT SITE CAMP CANOY
5 58 73078622651343 382614762533
5 57 ROCKY POINT
5 58 73078622434533 382443762353
5 57 LITTLE COVE POINT
5 58 73078622124100 382140762210
5 59 060868 060275  001  3  005
5 60 MARION ROSS       A
5 62 MARTHE COLE-JONES A
```

```
                    ******  M022022 ******
1  2 M022022
1  4 PA ACAD NS PHIL
1  7 CHESAPEAKE BAY SURVEYS (CALVERT CLIFFS) SURVEY REPORT  FOR
1  7 BALTIMORE GAS & ELECTRIC (BG&E) 1968 THRU 1975
1 10 CALVERT CLIFFS BASELINE STUDY
1 14 NORTH AMERICA, U.S., COASTAL, MARYLAND, CHES BAY
1 17 SURVEY ALSO INCLUDES : ROOTED AQUATIC ALGAE, PROTOZOA,
1 17 MACROINVERTEBRATES, FISHES
1 17 METHODS:
1 17 1968 THRU 1972: 5 HI & LO TIDE DATA, SPRING & FALL SEASON, 4 STATIONS
1 17 1973  CHEMICAL & PHYSICAL DATA UNDER SEPARATE COVER
1 17 1974 3 HI & LO TIDE DATA, FALL SEASON,  4 STATIONS
1 17 1974 DATA - SAMPLES AT 2 FT., NOT AT SURFACE
1 17 1975 6 FLOOD & EBB, 2 SEASONS
1 17 TRANSPARENCY  MEASUREMENTS IN 1972 AND 1974 WERE RECORED AS FEET,
1 17 (SECCHI DISC) BUT THE OBSERVED MEASUREMENTS APPEARS TO BE IN METERS.
1 17 DATA MUST HAVE BEEN MISLABELLED.
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    76  TURBIDITY, HACH TURBIDIMETER ( FORMAZIN TURB UNIT )
1 17    77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17    95  CONDUCTIVITY AT 25 DEGREES C (MIRCOMHOS)
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   310  BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
1 17   400  PH (STANDARD UNITS)
1 17   410  ALKALINITY, TOTAL (MG/L AS CACO3)
1 17   415  ALKALINITY, PHENOLPHTALEIN (MG/L AS CACO3)
1 17   440  BICARBONATE ION (MG/L AS HCO3)
1 17   445  CARBONATE ION (MG/L AS CO3)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   500  RESIDUE (SOLIDS) TOTAL (MG/L)
1 17   505  RESIDUE, TOTAL, VOLATILE (MG/L)
1 17   510  RESIDUE, TOTAL FIXED (MG/L)
1 17   610  NITROGEN, AMMONIA, TOTAL  (MG/L AS N)
1 17   615  NITRITE NITROGEN, TOTAL (MG/L AS N)
1 17   620  NITRATE NITROGEN, TOTAL (MG/L AS N)
1 17   625  NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   630  NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1 17   650  PHOSPHATE, TOTAL (MG/L AS PO4)
1 17   665  PHOSPHORUS, TOTAL (MG/L AS P)
1 17   671  PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
1 17   940  CHLORIDE (MG/L AS CL)
1 17   946  SULFATE, DISSOLVED ( MG/L AS SO4)
1 17   956  SILICA, TOTAL (MG/L AS SIO2)
1 17 31501  COLIFORM, TOTAL, MEMBRANE FILTER IMMED. M-ENDO MED 35C (#/100ML)
1 17 31616  FECAL COLIFORM, MEMB. FILTER, M-FC BROTH 44.5 C (#/100ML)
1 17 31751  PLATE COUNT, TOTAL, TPC AGAR 35 C/24HR (#/1 ML)
1 17 70505  PHOSPHATE, TOTAL, COLORIMETRIC METHOD (MG/L AS P)
1 17 98754  TURBIDITY, PHOTOMETRIC 420 MU (MG/L)
1 17 98764  NITROGEN, PARTICULATE (MG-AT/L AS N) <NSC>
1 18 DR. CLYDE GOULDEN
1 20 ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA/DEPT LIMN
1 21 19TH AND THE PARKWAY
1 22 PHILADELPHIA
1 23 PENNSYLVANIA
```

```
1 25 19103
1 27 3 TO 6 HIGH AND LOW TIDES SAMPLED 2X/ YR FOR 8 YRS AT 4 STATIONS
5 37 1  + HACH(FORMAZIN)  472
5 38 1                   461
5 39 1                  1465
5 40 1                  1610
5 41 1                   469
5 44 1 +FECAL COLIFORM   526
5 45 1                   462
5 46 1                    72
5 47 1                   894
5 48 1                   477
5 49 1                   420
5 53 1 SECCHI             79
5 54 1 CONDUCTIVITY      470
5 55 1 BICARBONATE ION   470
5 55 1 CARBONATE ION     433
5 55 1 TOTAL SOLIDS      462
5 55 1 TOTAL FIXED SOLIDS 465
5 55 1 VOLATILE SOLIDS   468
5 57 1 SOUTH KENWOOD BEACH
5 58 7307862299O354 382905762934
5 57 2 SOUTH LONG BEACH
5 58 73078622770188 382708762718
5 57 3 CAMP CANOY
5 58 73078622660017 382601762607
5 57 4 SOUTH ROCKY POINT
5 58 73078622440159 382405762419
5 59 060668 082875 000 0 004
5 60 MARIAN ROSS        A
5 62 MARTHE COLE-JONES A
```

```
                        ******  M022023 ******

1  2 M022023
1  4 US EPA REG 3
1  7 WATER QUALITY SURVEY OF THE CHESAPEAKE BAY IN THE VICINITY OF
1 17 SANDY POINT DATA REPORTS #13 (1968), #14 (1969), #22 (1970)
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, CHESAPEAKE BAY
1 17 1968 DATA ON DOMINANT PHYTOPLANKTON NOT ENCODED
1 17 ALL STATIONS AND ALL DATA CODED BY EPA AND IN STORET UNDER
1 17 AGENCY CODE : 11121RWQ
1 17 00010 WATER TEMP   BECKMAN SALIMETER (CENTIGRADE)
1 17 00070 TURBIDITY (JACKSON CANDLE UNITS)
1 17 00077 LIGHT EXTINCTION   SECCHI DISK    INCHES
1 17 00095 CONDUCTIVITY AT 25 DEGREES C (MICROOHMS)
1 17 00300 DISSOLVED OXYGEN    STANDARD METHODS  WINKLER  MG/L
1 17 00400 PH    FIELD PH METER    ?
1 17 00480 SALINITY    BECKMAN SALINOMETER    PPT
1 17 00310 BOD    STANDARD METHODS   5 DAY, 20 DEGREES CENT  MG/L
1 17 00660 INORGANIC PHOSPHORUS   MURPHY & RILEY (1962)    MG/L AS PO4
1 17 00625 TKN       STANDARD METHODS       MG/L AS N
1 17 00630 NO2 & NO3     STRICKLAND AND PARSONS     MG/L AS N
1 17 00610 NH3     PHENOL-HYPOCLORITE   MG/L AS N
1 17 00680 TOC   DOW-BECKMAN CARBONACEOUS ANALYZER  MG/L
1 17 00690 TOTAL CARBON    DOW-BECKMAN CARBON ANALYZER   MG/L
1 17 31506 COLIFORM  STAND METH  TUBE LACTOSE BILE  35 DEGREES CENT   MPN/100ML
1 17 32209 CHL A   STRICKLAND AND PARSONS     MG/L
1 17 31615 FECAL COLIFORM  STAND METH TUBE E.C.  45 DEGREES CENT    MPN/100ML
1 17 71886 TOTAL PHOSPHORUS MG/L AS PO4 MENZEL & CORWIN(1965);
1 17 MURPHY & RILEY (1962)
1 17 1968  16 STATIONS (3 AT 5 TRANSECTS PLUS CRAIGHILL LT)
1 17 1969  23 STATIONS (3 AT 5 TRANSECTS PLUS 2 TRANSECTS WITH 2 STATIONS
1 17 PLUS ONE TRANSECT WITH 3 STATIONS AND CRAIGHILL LIGHT)
1 17 1970  23 STATIONS
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    70  TURBIDITY, ( JACKSON CANDLE UNITS )
1 17    77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17    95  CONDUCTIVITY AT 25 DEGREES C (MIRCOMHOS)
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   310  BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
1 17   400  PH (STANDARD UNITS)
1 17   480  SALINITY - PARTS PER THOUSAND
1 17   610  NITROGEN, AMMONIA, TOTAL  (MG/L AS N)
1 17   625  NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   630  NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1 17   660  PHOSPHATE, ORTHO (MG/L AS PO4)
1 17   680  CARBON, TOTAL, ORGANIC (MG/L AS C)
1 17   690  CARBON, TOTAL (MG/L AS C)
1 17 31506  COLIFORM,TOTAL,MPN,CONFIRMED TEST,TUBE CONFIG. (MPN/100ML)
1 17 31615  FECAL COLIFORM, MPN, EC MED, 44.5C,(TUBE31614)(MPN/100ML)
1 17 32211  CHLOROPHYLL A (UG/L) SPECTROPHOTOMETRIC METHOD
1 17 71886  PHOSPHORUS, TOTAL, AS PO4 - MG/L
1 18 J.W. MARKS & D.W. LEAR
1 20 ANNAPOLIS FIELD OFFICE OF US EPA REGION 3
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
```

```
1 23 MARYLAND
1 25 21401
1 27 23 STATIONS (16 IN 1968) SAMPLED ONCE A MONTH FOR 25 MONTHS TOTAL
1 27 AT SEVERAL DEPTHS FOR PLUS OR MINUS 13 PARAMETERS.
1 27 NOT ALL STATIONS SAMPLED WITH SAME FREQUENCY
5 35 1 CHL A              459
5 37 1                     87
5 38 1                   1012
5 39 1 TOT & INORG       1614
5 40 1 NO2+NO3 TKN NH3  2701
5 42 1 TOC TC              66
5 44 1 &FECAL COLIFORMS  270
5 45 1                    887
5 46 1                    949
5 48 1                     43
5 49 1                    282
5 53 1 SECCHI             371
5 54 1 CONDUCTIVITY       707
5 57 AA-1 BUOY RBC
5 58 73079602855287 390858762527
5 57 AA-2 BUOY R 28C
5 58 73079612064010 391041762600
5 57 A-1 OFF TOWER/WINDMILL PT
5 58 73079602543505 390530762455
5 57 A-2 RED FLASHER 10C
5 58 73079602533378 390537762338
5 57 A-3 BLACK/WHITE BUOY 13B
5 58 73079602504537 390543762057
5 57 B-1 RED FLASHER 2 MAGOTHY RIVER
5 58 73079602351483 390318762543
5 57 B-2 RED NUN 4C
5 58 73079602333255 390335762325
5 57 B-3 BLACK FLASHER BELL 1
5 58 73079601493443 390434761943
5 57 C-1 OFF HOUSE TYDINGS-ON-THE-BAY
5 58 73079602241083 390218762403
5 57 C-2 RED FLASHER BELL 2C
5 58 73079602235056 390255762306
5 57 C-3 EDGE OF BUMPING GROUNDS
5 58 73079602204308 390240762038
5 57 D-1 OFF SANDY POINT
5 58 73079602033220 390032762320
5 57 D-2 RED FLASHER GONG 82
5 58 73078652925472 385957762242
5 57 D-3 SOUTH EDGE DUMPING GROUNDS
5 58 73078652913102 385930762112
5 57 E-1 OFF HACKETTS POINT
5 58 73078652845487 385858762447
5 57 E-2 RED FLASHER GONG 4
5 58 73078652833132 385833762312
5 57 E-3 OFF MATAPEAKE FERRY SLIP
5 58 73078652713402 385730762142
5 57 F-1 TOLLYS POINT BUOY 33
5 58 73078652650409 385600762549
5 57 F-2 MID BAY
```

```
5 58 73078652545203 385550762423
5 57 F-3 BRICKHOUSE BAR BUOY 20B
5 58 73078652533080 385538762300
5 57 G-1 OFF BEMBE BEACH
5 58 73078652771220 385712762720
5 57 G-2 BAY BELL BUOY
5 58 73078652870146 385804762716
5 57 CRAIGHILL LIGHT
5 58 73079612132442 391124762342
5 59 042268 120270 001 3 023
5 62 MARTHE COLE-JONES A
```

```
                    ******  M022024 ******
1  2 M022024
1  4 US EPA REG 3
1  7 WATER QUALITY SURVEY OF THE POTOMAC ESTUARY 1967 DATA REPORT
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, POTOMAC RIVER
1 17 REPORT ALSO INCLUDES BACTERIOLOGICAL DATA FROM EFFLUENT OF 4 SEWAGE
1 17 TREATMENT PLANTS SAMPLED OVER TWO WEEK PERIOD. THIS DATA
1 17 WAS NOT ENCODED.
1 17 ACCORDING TO AFO/EPA DATA SHOULD BE IN STORET UNDER AGENCY
1 17 CODE :11121TWQ FOR ESTUARY AND AGENCY CODE :11121UWQ FOR STP'S
1 17    10  TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    70  TURBIDITY (JACKSON CANDLE UNITS)
1 17    77  TRANSPARENCY, SECCHI DISC (INCHES)
1 17   300  OXYGEN, DISSOLVED (MG/L)
1 17   625  NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   630  NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1 17   631  NITRITE PLUS NITRATE, DISS. 1 DET. (MG/L AS N)
1 17   660  PHOSPHATE, ORTHO (MG/L AS PO4)
1 17   940  CHLORIDE (MG/L AS CL)
1 17 31506  COLIFORM,TOTAL,MPN,CONFIRMED TEST,TUBE CONFIG. (MPN/100ML)
1 17 31615  FECAL COLIFORM, MPN, EC MED, 44.5C,(TUBE 31614)(MPN/100ML)
1 17 31677  FECAL STREPTOCOCCI, MPN, AD-EVA, 35 C (MPN/100ML)
1 17 32211  CHLOROPHYLL A (UG/L) SPECTROPHOTOMETRIC METHOD
1 17 71886  PHOSPHORUS, TOTAL AS PO4 (MG/L)
1 18 ORTERIO VILLA, JR./ MEG MUNRO
1 19 301-224-2740
1 20 EPA/ANNAPOLIS FIELD OFFICE
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 22 STATIONS SAMPLED ONCE A WEEK FOR APPROXIMATELY 4 SEPARATE WEEKS
1 27 FOR PLUS OR MINUS 13 PARAMETERS
1 27 BACTERIOLOGICAL & TP:   2-14 MARCH
1 27 WATER QUALITY AND NUTRIENTS:   20-21 SEPT
1 27 BACTERIOLOGICAL AT 4 SEWAGE TREATMENT PLANTS:  3-21 FEBRUARY
5 35 1 CHL A              32
5 37 1
5 38 1                    32
5 39 1 TP INORG-P        239
5 40 1 TKN NO2 & NO3      64
5 44 1 & FECAL           388
5 45 1                   364
5 53 1 FECAL STREPTOCOCCI 194
5 54 1 SECCHI             32
5 55 1 CHLORIDES          32
5 57 CABIN JOHN BRIDGE
5 58 73078751500000 385500771000
5 57 CHAIN BRIDGE
5 58 73078750674080 385648770700
5 57 M STREET BRIDGE (ROCK CREEK)
5 58 73078750431281 385418770321
5 57 MEMORIAL BRIDGE
5 58 73078750223102 385230770212
5 57 14TH STREET BRIDGE
```

```
5 58 73078750223270 385237770220
5 57 HAINES POINT
5 58 73078750112330 385123770130
5 57 PENN AVE BRIDGE (ANACOSTIA RIVER)
5 58 73078750200185 385208770015
5 57 BOLLING AFB CAN BUOY 9
5 58 73078750011308 385010770138
5 57 BELLEVUE
5 58 73078740914445 384944770145
5 57 WOODROW WILSON BRIDGE
5 58 73078740724108 384740770218
5 57 BROAD CREEK
5 58 73078740520102 384500770212
5 57 PISCATAWAY CREEK
5 58 73078740223307 384230770237
5 57 DOGUE CREEK
5 58 73078740162428 384122770648
5 57 HALLOWING POINT
5 58 73078730775380 383758770730
5 57 INDIAN HEAD
5 58 73078731603254 383635771024
5 57 POSSUM POINT
5 58 73078731165106 383150771616
5 57 SANDY POINT
5 58 73078721865440 382854771640
5 57 SMITH POINT
5 58 73078721560100 382500771610
5 57 MARYLAND POINT
5 58 73078721121320 382112771230
5 57 NANJEMOY CREEK
5 58 73078720363520 382332770650
5 57 301 BRIDGE
5 58 73078625194350 382145765930
5 57 KEY BRIDGE
5 58 73078750440191 385409770411
5 59 670131 670921 001 4 022
5 60 MARTHE COLE-JONES  A
5 62 H.S. MILLSAPS      A
```

```
                    ****** M022025 ******
1  2 M022025
1  4 US EPA REG 3
1  7 WATER QUALITY SURVEY OF THE POTOMAC ESTUARY TRANSPORT SURVEY
1  7 DATA REPORT #20  1969-70
1 14 NORTH AMERICA,U.S.,MARYLAND, COASTAL, POTOMAC RIVER
1 17 OIL BARGE MAKING WEEKLY RUNS UP POTOMAC
1 17 RIVER TOOK SURFACE SAMPLES BY DIPPING BUCKET
1 17 DATA NOT YET KEYPUNCHED BY CBL/ DATA MAY BE IN STORET UNDER
1 17 AGENCY CODE :111230WQ
1 17 CODES USED BY EPA INCLUDE : 10,70,77,95,300,310,400,480,
1 17 403,610,630,660,680,681,32230,71845
1 18 J.W. MARKS/O. VILLA, JR.
1 19 301-224-2740
1 20 ANNAPOLIS FIELD OFFICE - EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 16 STATIONS SAMPLED 1 X /WEEK FOR 50-51 WEEKS FOR 11-13 PARAMETERS
5 35 1 CHL A
5 37 1
5 39 1 TP TDP FP
5 40 1 TKN TKND NO2 & NO3 NH3
5 42 1 TOC TOCD
5 45 1
5 53 1 CHLORIDES
5 57 HAINES POINT
5 58 73078603820020 380802763200
5 57 WOODROW WILSON BRIDGE
5 58 73078740724108 384740770218
5 57 BROAD CREEK
5 58 73078740520102 384500770212
5 57 PISCATAWAY CREEK
5 58 73078740223307 384230770237
5 57 DOGUE CREEK
5 58 73078740162428 384122770648
5 57 HALLOWING POINT
5 58 73078730775380 383758770730
5 57 INDIAN HEAD
5 58 73078731603254 383635771024
5 57 POSSUM POINT
5 58 73078731165106 383150771616
5 57 SANDY POINT
5 58 73078721865440 382854771640
5 57 SMITH POINT
5 58 73078721560100 382500771610
5 57 MARYLAND POINT
5 58 73078721121320 382112771230
5 57 NANJEMOY CREEK
5 58 73078720363520 382332770650
5 57 301 BRIDGE
5 58 73078625194350 382145765930
5 57 WICOMICO CREEK
5 58 73078614393408 381330764948
```

```
5 57 KINGCOPISCO CREEK
5 58 73078614013200 381030764120
5 57 PINEY POINT
5 58 73078693820020 380802763200
5 59 021869 042070 001 4 016
5 60 MARTHE COLE-JONES  A
5 62 H.S. MILLSAPS     A
```

```
                       ****** M022026 ******
1  2 M022026
1  4 USPHS-TREASURY DEPT
1  7 INVESTIGATIONS OF THE POLLUTION OF TIDAL WATERS OF MARYLAND AND
1  7 VIRGINIA (WITH SPECIAL REFERENCE TO SHELLFISH BEARING AREAS)
1  7 MARCH 1916 H.S. CUMMINGS PUBLIC HEALTH BULLETIN #74
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY AND TRIBS
1 18 LIBRARIAN
1 19 301 224 2740
1 20 EPA /ANNAPOLIS FIELD OFFICE
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 SINGLE SAMPLING BAY WIDE AT 1166 STATIONS FOR SALINITY, TURBIDITY, FECAL
1 27 COLIFORM IN WATER AND IN SHELLFISH
5 35 1
5 45 1
5 46 1
5 53 1 FECAL COLIFORM
5 54 1 FECAL COLIFORM IN SHELLFISH
5 59 021114 020515   001   1166
5 60 DON HEINLE
5 62 MARTHE COLE-JONES   U
5 63 UNNACCEPTABLE DATA FOR ENCODING; CONTAINS LITTLE WATER QUALITY DATA
5 63 BUT MAY PROVIDE DESCRIPTIVE EVIDENCE OF EARLY CONDITIONS IN CHESA-
5 63 PEAKE BAY AND TRIBUTARIES; POSSIBLY USEFUL IN TREND ASSESSMENT
```

```
                          ****** M022027 ******
1  2 M022027
1  4 PA ACAD NS PHIL
1  7 MORGANTOWN STATION AND THE POTOMAC ESTUARY: A 316 ENVIRONMENTAL
1  7     DEMONSTRATION FOR PEPCO VOL I,II,III  SUMMARY   SEPT 1977
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
1 17 SUMMARIES FINDINGS OF 1966-76 ANSP BASELINE STUDIES TREND (SEASONAL & YEARL
1 17     YEARLY) ANALYSES FOR SALINITY, TEMP, NUTRIENTS (TPO4, NO2&NO3,
1 17    NH3, TOC), DO,CO2, SILTATION & HEAVY METALS
1 17 SAMPLING DATES  1966-1976
1 17  FREQUENCY: ONCE PER MONTH FOR 11-12 MONTHS FOR 10 YEARS
1 17 SURFACE AND BOTTOM
1 17 3 STATIONS POPES CREEK, PLANT SITE, MORGANTOWN
1 18 LYNNE F. BERSETH
1 20 ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA (LIMNOL & ECOL) DIV)
1 21 19TH & THE PARKWAY
1 22 PHILADELPHIA
1 23 PENNSYLVANIA
1 25 19103
1 27 3 STATIONS SAMPLED ONCE A MONTH FOR APPROXIMATELY 11-12 MONTHS
1 27     A YEAR FOR 10 YEARS
5 38 1
5 49 1 TPO4   INORG P
5 40 1 NH3  NO2&NO3
5 42 1 TOC
5 45 1
5 46 1
5 53 1 HEAVY METALS
5 62 MARTHE COLE-JONES   U
5 63 NO RAW DATA, AVERAGED VALUES
```

```
                         ****** M022028 ******
1  2 M022028
1  4 PA ACAD NS PHIL
1  7 PRIMARY PRODUCTIVITY STUDIES IN THE LOWER POTOMAC RIVER NEAR
1  7    MORGANTOWN SES FOR PEPCO JULY 1974 (DATA 9-71 TO 6-73)
1 10 POROMAC RIVER (MORGANTOWN) BASELINE STUDY
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, POTOMAC RIVER
1 17 THE FOLLOWING PARAMETERS WERE MEASURED: SALINITY, TEMP, DO, SOLAR
1 17     RADIATION, CHLA, PHOTOSYNTHESIS (MGO2 PER M PER HR)
1 17 STATIONS ID'S ARE: PC, PS, M
1 17 DATA IN GRAPHS INCLUDES: NET & GROSS PHOTOSYNTHESIS, RESPIRATION OF
1 17    PLANKTON COMMUNITY, SURFACE CHL A, TOTAL SURFACE PHYTOPLANKTON,
1 17     CHL VS CELL COUNT, DIATOMS, DINOFLAGELLATES AND MICROFLAGELLATES AS PER
1 17   PERCENT TOTAL PHYTOPLANKTON
1 18 DR. DENNIS BURTON
1 19 301-274-3134
1 21 BENEDICT ESTUARINE RESEARCH LAB
1 22 BENEDICT
1 23 MARYLAND
1 25 20612
1 27 COLLECTIONS AT 6 PERIODS IN ANNUAL TEMPERATURE CYCLE
1 27   MARCH, MAY, JUNE, AUGUST, OCTOBER, NOVEMEBER
1 27   2 TIMES (OCCASSIONALLY 1 OR 3 TIMES PER MONTH FOR 12 MONTHS AT 3 STATIONS
5 35 A CHL A
5 38 1
5 45 1
5 46 1
5 53 1 PHOTOSYNTHESIS
5 54 1 SOLAR RADIATION
5 59 09XX71 06XX73  002  3  003
5 62 MARTHE COLE-JONES  U
5 63 THE DATA PRESENTED GRAPHICALLY
```

```
                    ****** M022029 ******
1  2 M022029
1  4 PA ACAD NS PHIL
1  7 PRODUCTIVITY STUDIES ON THE POTOMAC RIVER 1967-1970, 1971-1973
1  7      (PUBL OCT 1972 & JULY 1974 RESPCTIVELY)
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, POTOMAC RIVER
1 17 PARAMETERS INCLUDE TEMP., DO, PH, TURBIDITY(PHOTOMETER OR SECCHI), CHLORIDE
1 17    PLANKTON, TOTAL PRODUCTICITY
1 17 SAMPLING DATES:  6 JUNE 1967, 20 OCT 1970, SEPT 1971, JUNE 1973
1 18 DR. DENNIS BURTON
1 19 301-274-3134
1 20 ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA/DEPT LIMN
1 21 BENEDICT ESTUARINE RESEARCH LAB
1 22 BENEDICT
1 23 MARYLAND
1 25 20612
1 27 3 STATIONS WITH 3 TO 4 SUB-STATIONS EACH) SAMPLED 1 TO 2 WEEKS PER MONTH
1 27    FOR 16 MONTHS.  SURFACE AND BOTTOM.  SALINITY, TEMP, GROSS PRODUCTION,
1 27 AND SECCHI
5 36 1 TOTAL PRODUCTIVITTY
5 37 1
5 38 1
5 45 1
5 46 1
5 53 1 SECCHI
5 54 1 CHLORIDE
5 55 1 PLANKTON
5 59 060667 06XX73        003
5 62 MARTHE COLE-JONES A
```

```
                          ****** M022030 ******
1  2 M022030
1  4 PA ACAD NS PHIL
1  7 AN ANNUAL PLANKTON CYCLE ON THE POTOMAC RIVER IN THE VICINITY OF
1  7    MORGANTOWN S.E.S. JUNE 1969 TO MAY 1970 TO PEPCO MARCH 1972
1 10 POTOMAC RIVER (MORGANTWON) BASELINE STUDY
1 14 NORTH AMERICA, US,MARYLAND,COASTAL, POTOMAC RIVER
1 17 QUANTITATIVE BREAKDOWN OF DIATOMS AND DINOFLAGELLATES (& OTHERS) BY SPECIES
1 17  # CELLS/LITER, TEMP, PO4,SIO4, DO, SALINITY
1 18 R.A. MULFORD, C.W. HART, JR.
1 20 THE ACADEMY OF NATURAL SCIENCES OF PHILADELPHIA/DEPT LIMN
1 21 19TH AND THE PARKWAY
1 22 PHILADELPHIA
1 23 PENNSYLVANIA
1 25 19103
1 27 3 STATIONS SAMPLED ONCE PER MONTH FOR 11 MONTHS AT SURFACE AND BOTTOM FOR
1 27    ABOVE PARAMETERS ABOVE
5 36 1 PLANKTON
5 38 1
5 39 1
5 41 1
5 45 1
5 46 1
5 59 06XX69 05XX70  001  3  003
5 62 MARTHE  COLE-JONES  U
5 63 DATA IS GRAPHIC REPRESENTATION BY MONTH (AVERAGES) NO RAW DATA
```

```
                        ****** M022031 ******
1  2 M022031
1  4 PA ACAD NS PHIL
1  7 1976,1977 (2 REPORTS) BIOLOGICAL STUDIES ON THE POTOMAC RIVER
1  7 NEAR THE MORGANTOWN SES FOR PEPCO  (1978,1979) PUBL)
1 10 POTOMAC RIVER (MORGANTOWN) BASELINE STUDY
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, POTOMAC RIVER
1 17 1976: SALINITY, TEMPERATURE (BECKMAN)
1 17       LIGHT PENETRATION  (PHOTOMETER)
1 17       DO, CHL A, PHAEOPIGMENTS, PLANT CAROTENOIDS, PHYTOPLANKTON COUNTS
1 17 1977: TEMP, SALINITY, D.O., ACTIVE CHLA
1 17 1976 STATIONS ARE "PC, PS, M, AND 3 PLUME STATIONS A,B,C, NEAR 301 BRIDGE
1 17   INTAKE CHANNEL
1 17 STATION "PS" IS A DIFFERENT LOCATION THAN IN PREVIOUS YEARS
1 17      IN THIS STUDY, PS IS "LOCATED IN SES INTAKE CHANNEL ADJACENT TO CURTAIN
1 17      CURTAIN WALL"
1 17 "MP" IS MATHIAS POINT, PC,  CLIFFTON IS "CL", PLUME A IS "PLA"
1 17 "PP" IS PASQUAHANZA POND, "LCP" IS LOWER CEDAR POINT
1 18 F. EDWARD KRUEGER
1 20 ACADEMY OF NATUARL SCIENCES OF PHILADELPHIA
1 21 19TH AND THE PARKWAY
1 22 PHILADELPHIA
1 23 PENNSYLVANIA
1 25 19103
1 27 1976: NEARFIELD AND 3 DISCHARGE STATIONS SAMPLED ONCE PER MONTN FOR 12 MOS
1 27 1977:  ONCE PER MONTH FOR 12 MONTHS AT 6 STATIONS
1 27 TABLES OF SALINITY, CHL A;  GRAPHS OF DO, TEMP, LIGHT PENETRATION,
1 27 PHYTOPLANKTON, DIATOMS, DINOFLAGGELLATES, ETC.
5 35 1 CHL A PHAEO CARONTEN
5 36 1 PHYTOPLANKTON
5 37 1 LIGHT PENETRATION
5 38 1
5 45 1
5 46 1
5 59 01XX76 121977  001  3  006
5 62 MARTHE COLE-JONES A
5 63 ONLY PART OF THE DATA AVAILABLE AS RAW #'S THE REST
5 63 OF THE DATA PRESENTED GRAPHICALLY
```

```
                    ******  M022032 ******
1  2 M022032
1  4 C BIO LAB
1  7 POTOMAC RIVER 1977 ZOOPLANKTON SURVEY
1 10 POWER PLANT SITING PROGRAM (PPSP)
1 14 NORTH AMERICA, US, COASTAL, MARYLAND, POTOMAC RIVER
1 17 DATA ON CARDS OR TAPE UNDER PPSP CONTRACT
1 17 CONTACT BILL CAPLINS AT CBL
1 17 INCLUDES 7 STATIONS FROM STUART POINT TO SHERIDAN POINT
1 18 DR. DONALD HEINLE
1 19 301-326-4281
1 20 CHESAPEAKE BIOLOGICAL LABORATORY
1 21 P.O. BOX 38
1 22 SOLOMONS
1 23 MARYLAND
1 25 20688
1 27 7 STATIONS SAMPLED ONCE PER WEEK FOR 8 WEEKS SURFACE AND BOTTOM
5 35 1 CHL A
5 37 1  TRANSMITTANCE
5 38 1
5 42 1
5 43 1 TOTAL SESTON
5 45 1
5 46 1
5 53 1 PARTICULATE CARBON
5 59 041477 060277  001  4  007
5 60 DONALD R. HEINLE   A
5 62 MARTHE COLE-JONES A
```

```
                        ****** M022033 ******
1  2 M022033
1  4 C BIO LAB
1  7 1978 PATUXENT RIVER SURVEY
1 10 POWER PLANT SITING PROGRAM (PPSP)
1 14 NORTH AMERICA, US, MARYLAND, COASTAL, PATUXENT RIVER
1 17 DATA IS ON CARDS OR TAPE UNDER PPSP CONTRACT
1 17 CONTACT BILL CAPLINS AT CBL
1 17 12 STATIONS FROM WAYSONS CORNER TO JACK BAY
1 18 DR. DONALD R. HEINLE
1 19 301-326-4281
1 20 CHESAPEAKE BIOLOGICAL LABORATORY
1 21 P.O. BOX 38
1 22 SOLOMONS
1 23 MARYLAND
1 25 20688
1 27 12 STATIONS SAMPLED ONCE PER WEEK FOR 6 WEEKS AT SURFACE AND BOTTOM
5 35 1 CHL A
5 38 1
5 43 1
5 45 1
5 46 1
5 53 1 SECCHI
5 54 1 POC
5 59 032178 082378  001  4  012
5 60 DONALD R. HEINLE
5 62 MARTHE COLE-JONES
```

```
                    ****** M022034 ******
1  2 M022034
1  4 US EPA REG 3
1  7 WATER QUALITY OF THE POTOMAC ESTUARY GILBERT SWAMP AND ALLENS
1  7 FRESH AND GUNSTON COVE DATA REPORT #30 1970
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, POTOMAC RIVER
1 17    10 TEMPERATURE, WATER (DEGREES CENTIGRADE)
1 17    70  TURBIDITY (JACKSON CANDLE UNITS)
1 17    77 SECCHI DISC (INCHES)
1 17   300 OXYGEN, DISSOLVED (MG/L)
1 17   310 BIOCHEMICAL OXYGEN DEMAND (MG/L, 5 DAY - 20 DEG C)
1 17   400 PH (STANDARD UNITS)
1 17   610 NITROGEN, AMMONIA,TOTAL (MG/L AS N)
1 17   625 NITROGEN, KJELDAHL, TOTAL (MG/L AS N)
1 17   630 NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1 17   660 PHOSPHATE, ORTHO (MG/L AS PO4)
1 17   680 CARBON, TOAL ,ORGANIC (MG/L AS C)
1 17   690 CARBON, TOTAL (MG/L AS C)
1 17 31506 COLIFORM,TOTAL,MPN,CONFIRMED TEST, TUBE CONFIG.(MPN/100ML)
1 17 31615 FECAL COLIFORM,MPN, EC MED, 44.5 C(TUBE 31614)(MPN/100 ML)
1 17 32211 CHLOROPHYLL A (UG/L) SPECTROPHOTOMETRIC METHOD
1 17 71886 PHOSPHORUS, TOTAL, AS PO4 - MG/L
1 17 DATA HAS NOT BEEN ENCODED
1 18 LIBRARIAN
1 19 301-224-2740
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 10 STATIONS IN GILBERTS SWAMP SAMPLED PLUS OR MINUS 2 TIMES /MO
1 27 FOR 7 MOS FOR APPROX 11 PARAMETERS.12 STATIONS IN GUNSTON COVE
1 27 SAMPLED 1 TIME/MO FOR 5-7 MOS FOR 13 PARAMETERS
5 35 1 CHL A
5 37 1
5 38 1
5 39 1 TOT & INORG
5 40 1 NO2 + NO3  NH3  TKN
5 42 1 TOC
5 44 1
5 45 1
5 48 1
5 49 1
5 53 1 SECCHI
5 54 1 TOTAL CARBON
5 55 1 FECAL COLIFORMS
5 59 012870 121470  002  3  022
5 60 MARTHE COLE-JONES
5 62 MARTHE COLE-JONES
5 45 1
```

```
****** M022035 ******
1  2 M022035
1  4 US EPA REG 3
1  7 UPPER CHESAPEAKE BAY WATER QUALITY STUDIES BUSH RIVER, ROMNEY CREEK,
1  7 SPESUTIE NARROWS, SWAN CREEK 1968-71; C&D CANAL , CHESTER RIVER 1970;
1  7 SEVERN RIVER 1970-71; GUNPOWDER, MIDDLE, BIRD RIVERS 1971
1  7 DATA REPORT #32
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, UPPER CHESAPEAKE BAY AND TRIBS
1 17 DATA CODED IN STORET BY EPA (08-15-74), FOR ALL STATIONS,
1 17 UNDER AGENCY CODE : 1113WSWO
1 18 LIBRARIAN
1 19 301-224-2740
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 A TOTAL OF 65 STATIONS SAMPLED AT VARYING FREQUENCY
1 27 FOR UP TO 17 PARAMETERS
5 35 1 CHL A
5 38 1
5 39 1 TOT  &  INORG
5 40 1 TKN  NO2+NO3  NH3
5 42 1 TOT
5 44 1
5 45 1
5 46 1
5 48 1
5 49 1
5 53 1 SECCHI
5 54 1 CONDUCTIVITY
5 55 1 TOTAL CARBON
5 56 1 FECAL COLIFORMS
5 59 111968 062271  001  3 065
5 60 MARTHE COLE-JONES
```

```
                       ******  M022036 ******
1  2 M022036
1  4 US EPA REG 3
1  7 WATER QUALITY SURVEY OF THE ANNAPOLIS METROPOLITAN AREA
1  7 DATA REPORT #10 1967
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY, SELECTED TRIBS
1 18 LIBRARIAN
1 19 301-224-2740
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 A TOTAL OF 67 STATIONS SAMPLED WITH FREQUENCY RANGING FROM ONCE
1 27 PER MONTH FOR 4 MOS, TO ONCE A DAY FOR 1 WEEK FOR +/- 13 PARAMETERS
5 35 1 CHL A                 500
5 37 1                        24
5 38 1                        60
5 39 1 TOT TOT-DISS,        1000
5 40 1 TKN TKN-DISS NO2+NO3 1500
5 43 1 NON FILTER RESIDUE     24
5 44 1 & FECAL COLIFORMS    1170
5 45 1                       500
5 53 1 SECCHI                266
5 54 1 CHLORIDES             500
5 59 050267 080167     67
5 60 MARTHE COLE-JONES
```

```
                    ******  M022037 ******
1  2 M022037
1  4 US EPA REG 3
1  7 SPECIAL WATER QUALITY SURVEYS OF THE POTOMAC RIVER BASIN
1  7 ANACOSTIA ESTUARY 1970, WICOMICO RIVER AND ST. CLEMONT AND BRETON
1  7 BAYS 1971, OCCOQUAN BAY 1971  DATA REPORT #33
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, POTOMAC RIVER
1 18 LIBRARIAN
1 19 301-224-2740
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 A TOTAL OF 30 STATIONS SAMPLED WITH VARYING FREQUENCY (FROM ONCE , TO
1 27 ONCE A MONTH FOR 6 MOS, TO ONCE A WEEK FOR 8 WKS ) FOR +/- 18 PARAMETERS
5 35 1 CHL A             52
5 37 1                   40
5 38 1                   52
5 39 1  TOT & INORG     240
5 40 1 TKN NO2+NO3 NH3  390
5 42 1 TOC               74
5 43 1 TOTAL             31
5 44 1                   16
5 45 1                  130
5 46 1                   11
5 49 1                   27
5 53 1 FECAL COLIFORMS   43
5 54 1 SECCHI            18
5 55 1 CONDUCTIVITY      11
5 56 1 TOTAL CARBON      41
5 59 031870 110471  001  3  030
5 60 MARTHE COLE-JONES
```

```
                          ****** M022038 ******
1  2 M022038
1  4 US EPA REG 3
1  7 WATER QUALITY SURVEY OF THE UPPER POTOMAC ESTUARY ENFORCEMENT
1  7 CONFERENCE AREA  DATA REPORT #29 1970
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESPEAKE BAY
1 17 STATIONS ENTERED IN STORET UNDER AGENCY CODE : 1113POEN
1 17 DATA MAY ALSO BE ENTERED IN STORET
1 17 STATIONS USUALLY INCLUDE 3 SAMPLING SITES ON A TRANSECT : MARYLAND
1 17 SIDE, MID CHANNEL, VIRGINIA SIDE FOR SURFACE SAMPLES. BOTTOM
1 17 SAMPLES TAKEN ONLY AT MID CHANNEL
1 27 11 STATIONS SAMPLED 5 TIMES FOR FECAL BACTERIA AND D.O. ,
1 27 SAMPLED ONCE FOR NUTRIENTS
5 35 1 CHL A             38
5 38 1                 244
5 39 1 TOT  INORG       92
5 40 1 TKN NO2+NO3 NH3  138
5 42 1 TOC              22
5 45 1                 244
5 49 1                  24
5 53 1 SECCHI
5 54 1 FECAL COLIFORMS  145
5 55 1 FECAL STREPTOC   145
5 59 081370 091470  002  4  011
5 60 MARTHE COLE-JONES
```

```
                    ****** M022039 ******
1  2 M022039
1  4 US EPA REG 3
1  7 SURVEY RESULTS OF CHESAPEAKE BAY INPUT STUDY 1969-70
1  7 DATA REPORT #31
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, CHESAPEAKE BAY
1 17 DATA IS SUMMARIZED IN EPA TECHNICAL REPORT #47 (ASSN. NO. M022007)
1 18 LIBRARIAN
1 19 301-224-2470
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 9 TO 12 STATIONS SAMPLED APPROX ONCE A WEEK FOR 14 MOS FOR +/- 11 PARAMETER
5 35 1 CHL A                   16
5 38 1                         18
5 39 1 TP TPD INORG          2000
5 40 1 TKN TKND NO2+NO3 NH3 2700
5 42 1 TOC                    700
5 45 1                        725
5 49 1                          3
5 53 1 TOT CARBON             230
5 59 061169 090970  001  4  012
5 60 MARTHE COLE-JONES   A
```

```
                          ******  M022040 ******
 1  2 M022040
 1  4 US EPA REG 3
 1  7 POTOMAC ESTUARY WASTEWATER TREATMENT PLANTS SURVEY
 1  7 DATA REPORT #27 1970
 1 14 NORTH AMERICA, U.S., MARYLAND,VIRGINIA, COASTAL, POTOMAC RIVER
 1 27 11 STATIONS SAMPLED 5 TIMES FOR 7 PARAMETERS; 10 ADDITIONAL STATION
 1 27 SAMPLED 1 TIME FOR SAME 7 PARAMETERS
 1 18 LIBRARIAN
 1 19 301-224-2470
 1 20 ANNAPOLIS FIELD OFFICE/EPA
 1 21 ANNAPOLIS SCIENCE CENTER
 1 22 ANNAPOLIS
 1 23 MARYLAND
 1 25 21401
 5 39 1 TOT & INORG        128
 5 40 1 NH3 NO2+NO3 TKN    195
 5 42 1 TOC                 65
 5 53 1 TOT CARBON          55
 5 59 041270 091570  001  5  021
 5 60 MARTHE COLE-JONES   U
 5 61 DATA IS UNACCEPTABLE FOR CODING
```

```
                    ****** M022041 ******
1  2 M022041
1  4 US EPA REG 3
1  7 NUTRIENT DATA ON SEDIMENT SAMPLES OF THE POTOMAC ESTUARY 1966-68
1  7 DATA REPORT #11
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, POTOMAC RIVER
1 17 DATA NOT PUNCHED BY EPA/STORET, BUT STATIONS IN STORET UNDER
1 17 AGENCY CODE : 1113PESE
1 18 LIBRARIAN
1 19 301-224-2740
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 A TOTAL OF 21 STATIONS WITH 3-5 SUBSTATIONS EACH SAMPLED DURING
1 27 4 SAMPLING PERIODS FOR UP TO 16 PARAMETERS
5 35 1 CHL A
5 39 1 TOT  INORG  & BOT DEPOS
5 40 1 TKN NH3
5 51 1 DISS & BOT DEPOS
5 53 1 WET WEIGHT
5 54 1 DRY WEIGHT
5 55 1 VOLATILE WEIGHT
5 59 030366 022368  001  4  069
5 60 MARTHE COLE-JONES
```

```
                                ******  M022042 ******
1  2 M022042
1  4 US EPA REG 3
1  7 CONSOLIDATED WATER QUALITY SURVEY OF THE POTOMAC ESTUARY
1  7 DATA REPORT #25 1970
1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, POTOMAC RIVER
1 17 DATA IN STORET UNDER AGENCY CODE : 11121TWQ
1 18 LIBRARIAN
1 19 301-224-2470
1 20 ANNAPOLIS FIELD OFFICE/EPA
1 21 ANNAPOLIS SCIENCE CENTER
1 22 ANNAPOLIS
1 23 MARYLAND
1 25 21401
1 27 31 STATIONS SAMPLED ONCE A WEEK FOR 12-15 WEEKS AT SURFACE AND
1 27 BOTTOM FOR UP TO 16 PARAMETERS
5 35 1 CHL A              300
5 38 1                    700
5 39 1 TOT  INORG        1200
5 40 1 TKN NH3 NO2+NO3   1750
5 42 1 TOC                440
5 44 1                      5
5 45 1                    700
5 46 1                    500
5 49 1                    240
5 53 1 CONDUCTIVITY       500
5 54 1 SECCHI             315
5 55 1 FECAL COLIFORMS     20
5 56 1 TOTAL CARBON        81
5 59 040770 120870  001  4  031
5 60 MARTHE COLE-JONES
```

```
                          ******  M022043 ******
 1  2 M022043
 1  4 US EPA REG 3
 1  7 WATER QUALITY SURVEY OF THE POTOMAC ESTUARY EMBAYMENTS AND
 1  7 TRANSECTS DATA REPORT #28 1970
 1 14 NORTH AMERICA, U.S., MARYLAND, COASTAL, POTOMAC RIVER
 1 17 DATA IN STORET UNDER AGENCY CODE : 1113PEET
 1 18 LIBRARIAN
 1 19 301-224-2470
 1 20 ANNAPOLIS FIELD OFFICE/EPA
 1 21 ANNAPOLIS SCIENCE CENETER
 1 22 ANNAPOLIS
 1 23 MARYLAND
 1 25 21401
 1 27 25 STATIONS SAMPLED ONCE A MONTH FOR 6 MOS FOR +/- 12 PARAMETERS
 1 27 14 MORE STATIONS SAMPLED ONCE A MONTH FOR 2 MOS FOR  SAME
 5 35 1 CHL A              154
 5 38 1                    171
 5 39 1 TOT & INORG        342
 5 40 1 TKN NO2+NO3 NH3    513
 5 42 1 TOC                106
 5 45 1                    171
 5 46 1                     69
 5 53 1 TOTAL CARBON        24
 5 54 1 SECCHI             171
 5 55 1 CONDUCTIVITY        69
 5 59 022570 070970  001  3  039
 5 60 MARTHE COLE-JONES
```

```
1  2 M022044                ******  M022044 ******
1  4 USPHS HEW
1  7 INVESTIGATIONS OF THE POLLUTION AND SANITARY CONDITIONS OF THE POTOMAC
1  7 RIVER WATERSHED WITH SPECIAL REFERENCE TO SELF PURIFICATION AND
1  7 SANITARY CONDITIONS OF SHELLFISH IN THE LOWER POTOMAC RIVER
1  7 HYGENIC LABORATORY #104 FEBRUARY 1916 WASH.GOVT PRINTING OFFICE
1  7 HUGH S. CUMMINGS,W.C. PURDY, H.C. RITTER
1 14 NORTH AMERICA, U.U., MARYLAND, COASTAL, POTOMAC RIVER
1 17 POLLUTION SURVEY INCLUDES NORTH AND SOUTH BRANCH OF POTOMAC,
1 17 SHENANDOAH AND MONACACY RIVERS. SELF PURIFICATION STUDY IN THE
1 17 LOWER RIVER (BELOW WASH D.C.) AND ESTUARY INCLUDES OCCASIONAL
1 17 ANALYSIS OF THE FOLLOWING: B.COLI (NOW E.COLI)D.O.,BOD,TURBIDITY,
1 17 SUBMERGED PLANTS, PLANKTON, BOTTOM SAMPLES AND SHELLFISH. METHODS
1 17 BASED ON STANDARD METHODS AMERICAN PUBLIC HEALTH ASSOC 1912 ED
1 17 REPORT INCLUDES DESCRIPTIVE ANALYSIS OF POLLUTION STATUS
1 17 (POINT SOURCES) FOR VARIOUS POINTS ALONG POTOMAC RIVER.ACTUAL RAW DATA
1 17 IS MINIMAL, FREQUENTLY REPRESENTING A ONE TIME SAMPLING AT A LARGE
1 17 NUMBER OF STATIONS , OR SHOWING AVERAGED DATA
1 18 LIBRARIAN
1 19 301-496-5511
1 20 NATIONAL LIBRARY OF MEDICINE/HEW
1 21 8600 ROCKVILLE PIKE
1 22 BETHESDA
1 23 MARYLAND
1 25 20209
5 37 1
5 40 1 NH3 NO2 NO3
5 43 1 TOTAL
5 43 1 TOT & FIXED
5 44 1
5 46 1
5 49 1
5 52 1
5 53 1
5 53 1 TOTAL PLATE COUNT
5 54 1 CHLORINE
5 60 MARTHE COLE-JONES   U
```

Accessing the Eutrophication Data base

At the time of this report the Eutrophication Data base consists of the data sets described in detail in this appendix. One should note that there assession number/data set references in the directory for which no actual data exists in the project data base. Only the data sets described by the individual, detailed descriptions beginning on page 9 of Appendix B exist as machine readable entities in the data base.

At the present time, and until the transfer to STORET and/or the Chesapeake Bay Program Database, the data base is available through the facilities of the Univeristy of Maryland Computer Science Center, specifically on the UNIVAC 1108. Access to this computer system may be arranged as indicated for access to the climatic data. Prior to transfer to the permanent repository, the data base may exist in mass storage and on magnetic tape but a copy of each data set will exist on a reel of magnetic tape (reel number P10934) at the Computer Science Center. The first file on tape P10934 contains the climate data as documented in Apendix A. The third file on this tape contains the symbolic listing of, and the machine executable (absolute) code of a program which may be used to copy selected data sets from the tape to mass storage files. The mass storage files may be printed on a high-speed printer, punched onto cards, used as data files for analysis programs or copied to magnetic tape for transportation to other computer facilities.

Since we anticipate that additional data sets will be added to the database while it is resident on the Univeristy of Maryland system, the data extraction program will produce, upon request, a listing of the data sets currently on tape P10934. Alternatively it will accept as input, the name of data set and respond by creating a mass storage file, moving the tape to the proper location and copying the data set from tape to the mass storage file.

Operation of the Data Set Extraction Program

The following sequence of computer operating system commands may be used to access individual data sets in the data base.

```
@CAT,P DATAPULL.
@ASG,T TAPE.,U9S,P10934
@MOVE T.,1
@COPY,G TAPE.,DATAPULL.
@XQT DATAPULL.FIND
```

The program will query the user as to what action is requested. The two possible actions are:

1 Output a list of data sets in the data base;
2 Copy a data set from the data base to mass storage.

The program will print

```
DO YOU WISH A LIST OF DATA SETS   RESPOND (YES/NO)
```

A YES will cause a list of the currently available data sets to be displayed at the user's terminal and a similar list to be written to a temporay file named 14. This file <14.> may be examined with the Text Editor and will serve as reference during the life of the computer run. The program will then query the user as if a NO had been entered.

A NO will cause the program to print

```
ENTER THE ASSESSION NUMBER OF THE DESIRED DATA SET
 (TERMINATE PROGRAM BY ENTERING @EOF)
```

The user should respond by typing in at the keyboard of the terminal the 7 character assession number of the desired data set. Each entry must be on a separate line but multiple requests may be entered via the keyboard or by typing them into a temporary data file and @ADD'ing the file. In either case, the proper termination signal to the program is the image @EOF.

Data sets extracted by the program will now exist in mass storage as permanent (cataloged),public SDF or data files. Such files will be maintained in mass storage for 20 days unless accessed by any user. The files will be afforded neither read nor write protection and thus may be destroyed (in mass storage) by certain Text Editor commands (CHANGE, DELETE) and by some operating system commands, (@DELETE <filename>, @DATA,I <filename>).

The contents of each data set may be printed on the high-speed printer by entering the command @SYM,U <filename>,,PRA where <filename> (entered without the brackets) is the assession number of the dataset. CN-13 (latest version) discussess other operating system commands which may be used to examine or manipulate the data sets.

Data set acquisition

Data from Automated Data Systems'

Data sets acquired from automated data systems are usually still in their orginal format when made available to this project. Since these data sets are machine (computer) readable the most effecient way to convert them to the eutrophication project standard format (E-2) is through a computer translation program. A unique translation program is required for each different "foreign" or input data set but the design concept is the same for all. All computer activities associated with a data set are keyed to the assession number of the data set. The assession number is the root of any related filename.

Parameter Identification

Each unique parameter in the "foreign" or input data set must be identified and an exact determination made of the methods used to calculate that parameter. A look-up or translation table containing code pairs (old-new) for each parameter in the data set is created. The old code is the parameter code in the "foreign" or input data set and the new code is the corresponding STORET code to be used in the eutrophication project data set. The code translation file name consists of the assession name root and the prefix 'CT'. Any new paramters which occur in the input data set are added to the file

PCODE.

Data from Non-Automated Sources

Publications and other documentation concerning a data set not available from an automated data system are used to identify the methods used in the collection of the observations/measurements. In the case of some, especially older, data sets the techniques used by Marthe Cole-Jones to properly identify these methods seem worthy of Sherlock Holmes. A STORET parameter code from the STORET code book or a locally generated pseudo STORET code is associated with each unique parameter and encoded onto the E-2 format data sheets with the companion observation or measurement. A codebook containing instructions for encoding the data sheets has been prepared. The same format (E-2) is used for data sets from non-automated and from automated data systems. The encoded data sheets are used in entering the data directly into a computer data file by means of an interactive terminal or are the basis for creating punch cards on a keypunch. Punch card decks are submitted to the computer from CBL via a remote job entry (RJE) port. As is the case with data from automated data system the assession number of the data set is the root of the data set computer file identification name. New parameters encountered in the data set are added to the file PCODE.

Verification

Data which exists in a computer data base system are isolated from the publications, reports or other documentation of the validity of the original measurement techniques. Quality assurance for this aspect of the data collection activites is the responsibilty of many members of the project management team. Comparisons of computer accessable data with their sources is also difficult since the coding sheets do not accompany the data files. Quality assurance in this area is clearly a primary function and responsibility of the data base manager.

Verification of translations form automated data systems

An exploratory analysis of the "foreign" data format is conducted to determine the form of expression and range of values. A candidate translation program is developed, usually in a programing language designed for character manipulation. A test data set containing an example of all known variations of each field is constructed and translated to E-2 format by the candidate routine. The test data and the corresponding translation are 100% verified and the translation program corrected as necessary. Information (number of locations, dates, records, etc.) on the translation is generated by the translation program and this information is compared to both the output and the input data. The translation program and the E-2 formatted data set generated by it are not accepted until these descriptions are in agreement. After this type of test is successfully completed, the translation output is not verified on a character by character basis.

Verification of manually entered data sets

The original encoding sheets are compared to the hardcopy output on a 100%, character by character, line by line basis. All noted discrepencies are corrected before the data set is accepted by the data base manager.

"Coded" Parameter Codes

Many computer programs in the project calculate a "hashed" address when a 5 digit STORET parameter code is encountered. This is necessary to reduce the parameter code related storage requirements from a minimum of 99999 (5 digits) to a few hundred locations. A special code number is used in the hashing routine to generate a unique storage address for each STORET parameter code. When new parameter codes are added to the file PCODE., a check must be made to confirm the validity of the existing special code or to calculate a new one. The program CODEHASH does the checking.

Data base design

Data storage and retrieval systems, regardless of the medium, must accurately retain and reproduce the original information. In an automated data storage/retreval/manipulation or data base system, positive steps must be taken to ensure that all information stored in the data base system is, in actuality, an exact representation of the information supplied for entry. In such a data base system, an essential design criterion requires that authorized revisions of the data base are retained as unabiguous alterations to one 'master' set of records which may then be copied for added security. Additionally, the data base storage mechanisms should be conservative of the storage resource.

Eutrophication Project Data Codebook

Overview

Meaningful water quality data collection efforts precisely define each parameter of interest and locate the measurement of each parameter at a fixed point in space and time. The eutrophication project data format (E-2) is designed to record, in a unified format, the data collection efforts of many different researchers who used a variety of specailized data recording schemes. Format E-2 comprises three record types which, in combination, serve to relate the measurement of each parameter with the identification code of that parameter, to further identify the location, date, time and depth at which the measurement was made as well as to link the information to the person, group or agency responsible for the original collection. The three record types are (1) header records, (2) date/location records and (3) data records. Header records (card type 1) are used to name the station or collection location. The intended use is to provide visual identification for station locations during the verification and editing of data. Date/location records (card type 2) are formatted to record the data collection date, the location, to the nearest second of latitude and longitude, and the maximum water depth at the station. Data records (card type 3) are used to record up to four data measurements. Each measurement consists of the parameter identifier or code, the sample depth and the value of the measurement. A time field is used to record the time of collection (when known) of the data groups recorded on the same record(card).

1. General Introduction

The Eutrophication project data format (E-2) consits of three different card types. Each card type has the card type designation (1, 2 or 3) in column 80. The identification number of the data set (the assession number) is encoded in the first seven card columns of each card of all three card types. The assession number is coded in the seven (7) column block in the upper left of the E-2 coding sheet. The assession number does not change within a data set.

2. Card Type 1

2.1. ASSESSION NUMBER (Col 1 - 7)

As noted in the introduction, the assession number occupies the first seven positions of all cards, regardless of type. The assession number is encoded by placing it in the small upper left hand block on each E-2 coding sheet. The data entry person will punch that block as the first seven positions of all cards, thus position numbering for all cards starts with col 8.

2.2. DESCRIPTION (Col 8 - 78)

The body of card type 1 is free field and is intended to be used to record the name (and optional number designation) for each station and its associated data. The information may be coded in card columns 8 through 78 inclusive. This card may also be used to record anomalies in the data, either in the original data or in data translation to E-2 format. When a comment about the data should be printed along with any analysis of the data, enter a "*" (without the quotes) in col 8 and then enter the comment in the remainder of the field (up to col 78). The text in col 8 - 78 of card type 1 is not controlled since there is no intention for using the contents of this field an a search algorithm.

2.3. NEXT CARD (Col 79)

Column 79 is the Next Card Field and is coded with the type designation of the next card in the actual sequential order of the coded data set. Since card type 1 may be repeated and since the last card type 1 for a station must be followed by a card type 2, the possible valid entries for the next card field on this card type are either 1 or 2.

3. CARD TYPE 2

3.1. ASSESSION NUMBER (Col 1 - 7)

The assession number coded in the upper left of the form will be punched as the first field (7 columns) of card type 2. The 7 character code is NOT encoded on the coding form as part of the card.

3.2. DATE (Col 8 - 13)

Code the last two digits of the year of sampling date in columns 8 and 9. Code the numerical value of the month of the sampling date (January 1, July 7, December 12) in col. 10 and 11. The two digit day of the month is coded in col. 12 and 13.

3.3. LOCATION (Col 14 - 27)

The LOCATION field (col 14 - 27) is used to encode the Maryland/Virginia grid locator, a construct of the latitude and longitude of the station location.

3.3.1. Construction of the Md/Va Grid Locator

The description of and instructions for constructing a grid locator are contained in the NOAA - Environmental Data Base Directory Handbook for Interviewers, available from the Data Index Branch, National Oceanographic Data Center, 2001 Wisconsin Avenue N.W., Washington, D.C. 20235, (202) 634-7298. A grid locator number can be constructed by interleaving the comparable place digits of latitude and longitude. The first digit (col 14) of the grid locator is the quadrant and will always be a 7 for data for the Chesapeake Bay program. The remaining digits are:

(col 15) tens digit of degrees latitude;
(col 16) hundreds digit of degrees longitude;
(col 17) tens digit of degrees longitude;
(col 18) units digit of degrees latutude;
(col 19) units digits of degrees longitude;
(col 20) tens digit of minutes latitude;
(col (21) tens digit of minutes longitude;
(col 22) units digit of minutes latitude
(col 23) units digit of minutes longitude;
(col 24) tens digit of seconds latitude;
(col 25) tens digit of seconds longitude;
(col 26 units digit of seconds latitude;
(col 27) units digit of seconds longitude;

3.4. BOTTOM DEPTH (Col 28 - 32)

The bottom depth at the station location, if known, is coded in meters and tenths with an explicit decimal point. If the depth is known in feet, not meters, the value in feet is coded and a <1> is coded in the next field (DEPTH CODE MODIFIER).

3.5. DEPTH CODE MODIFIER (Col 33)

The Depth Code Modification field is used to indicated the units used to record both the bottom depth and the individual sample depths. Thus the units of measurement must be consistant throughout the data for an individual station. No entry is required for depths which are recorded in meters. Code a 1 for depths in feet.

3.6. LATITUDE (Col 34 - 39)

The station latitude is recorded, to the nearest second, in this field. Left justify the field when the full precesion is not known.

3.7. LONGITUDE (Col 40 - 46)

The station longitude is coded in this field. Left justify the field when the full precesion is not known.

3.8. UNASSIGNED POSITIONS (Col 47 - 78)

These positions on card type 2 are presently assigned.

3.9. NEXTCARD (Col 79)

The only valid entry for this field is a <3> since a single card type 2 is permitted.

4. CARD TYPE 3

4.1. TIME (Col 8 - 11)

The time of the collection of the sample is coded in hours (col 8 and 9) and minutes (col 10 and 11) based on a 24 hr clock and Eastern Standard Time.

4.2. DATA GROUP

Four data groups may be coded on on card type 3 if all of the observations were made at the time coded on the card. Additional data groups for the same sample time are coded on succeeding cards with the time field codedfor each card. Each new sample time within a single sample day requires a new card type 3.

4.2.1. PARAMETER CODE (Col 12-16, 28-32, 44-48, 60-64)

The project employs STORET parameter codes and descriptions to identify sampling activities. Codes not found in the STORET documentation are locally generated. Periodically, STORET is supplied with a list of code requests and subsequently the locally generated codes are replaced by the new STORET codes.

4.2.2. CODE MODIFICATION (Col 17, 33, 49, 65)

Each Code Modification field refers to its associated parameter code and observation/measurement and/or sample depth. This field is used to modify or codify the compainion field according to the meaning of the code modifier. The following are the current code modifiers and their meanings.

CM 1 STORET code units mg/l recorded data units ug-at/l
CM 2 STORET code units mg/l recorded data units mg-at/l
CM 5 STORET code units umhos recorded data units mhos
CM 6 STORET code units mg/l recorded data units meql/l

CM 7 STORET code units umhos recorded data units mmhos
CM 8 STORET code units mg/l recorded data units uncorrected ug-at/l
CM 9 STORET code units mg/l recorded data units uncorrected mg-at/l

4.2.3. SAMPLE DEPTH (Col 18-21, 34-37, 50-53, 66-69)

Sample depths (if known) are coded in meters and tenths except as noted in the documentation for the bottom depth field. Observations given as surface are coded as 0.5 m. All depth entries should be coded with explicit decimal points.

4.2.4. OBSERVATION or MEASUREMENT (Col 22-27,38-43,54-59,70-76)

The observation or measurement for the parameter coded in the adjacent paramter field is entered with an explicit decimal point. Values not requiring special treatment (a code modifier) range from 999999 to 0.00001.

4.3. NEXT CARD (Col 79)

Code a <3> if more card type 3 records follow the present card or code a <1> to indicate that the next card is that of a new station. Code a <z> in this field on the last card in the data set.

Appendix C

Fisheries Catch Data Documentation

R. E. Ulanowicz

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE

Appendix C

Robert E. Ulanowicz

The cumulative catch statistics and the environmental data used in the multiple regression analysis are stored on tape P10934, file 12, element DATALL (via the @COPY,G option) at the University of Maryland Computer Science Center.

All of the data for a single year are stored on five consecutive records of 76 characters length according to the format [I4,12F6.2/4(4X,12F6.2/)]. The first integer variable identifies the year in which the statistics were collected. The next 24 values give the Maryland catch in 1000 pounds of the following commerical species:

1. Alewife
2. Bluefish
3. Butterfish
4. Croaker
5. Flounder
6. Menhaden
7. Scup
8. Black seabass
9. Weakfish
10. American shad
11. Spot
12. Striped bass
13. White perch
14. Yellow perch
15. Hard crab
16. Soft crab
17. Oyster meat
18. Maryland Catch Total
19. Black drum
20. Catfish & Bullheads
21. Eel
22. Gizzard shad
23. Soft clam
24. Northern puffer

The remaining 26 variables characterize the environment during that year. Variables 25-28 are the average daily salinity, water temperature, air temperature and precipitation, while variables 29-32 are the cumulative excesses of the same variables taken in the same order. Cumulative annual deficits in salinity, water temperature and air temperature occur in positions 33-35, while the extremes (high and low) of salinity, water temperature and air temperature alternate in positions 36-41. Extreme daily rainfall occupies slot 42. Episodes of high and low (respectively) salinity, water temperature, air temperature and precipitation round out the series in the last eight values. These last 26 variables are described in Chapter D.

Missing data are denoted by a value of -1. The years 1938 through 1976 are presented, so the element consists of 195 records.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIH, EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

Appendix D

Climatic Factors Influencing Commercial Seafood Landings in Maryland[1]

Robert E. Ulanowicz
Mohammed Liaquat Ali[2]
Alice Vivian[3]
Donald R. Heinle[4]

University of Maryland
Chesapeake Biological Laboratory
Solomons, Maryland 20688

William A. Richkus
J. Kevin Summers

Martin Marietta Corporation
Environmental Center
Baltimore, Maryland 21227

---

[1] Contribution XXXX, Center for Environmental and Estuarine Studies of the University of Maryland.

[2] Senior Scientific Officer, Fisheries Campus Chandpur, P.O. Baburhat, Dist Comilla, Bangladesh.

[3] Sperry-Univac Corporation, Lexington Park, Maryland 20653.

[4] CH_2M Hill, 1500 114th Avenue S.E., Bellevue, Washington 98004.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA. OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE 1980 860-839
TYPING GUIDE SHEET

Abstract

Multivariate correlation of Maryland commercial fish and shellfish harvests with records of air and water temperatures, salinity, and precipitation yields provocative results. Greater than 50% of the variation in catch of all but one of seven commerically important species in Maryland waters could be explained by appropriate annual characterizations of forty years of daily environmental records. Many of the terms in the regressions agreed with previous qualitative hypotheses about factors affecting the stock sizes of these fish and shellfish, but causal links could not be unequivocally identified. The results should help in the organization of further research and management concerning these species and may afford estimates of catches one or more years into the future.

Introduction

Annual population levels of commercially harvested fish and shellfish usually fluctuate widely over the years. Such variation is often attributed to the strong influence of important environmental variables, such as fluctuation of water temperature, upon spawning success (Sissenwine, 1978). Environmental variables may directly affect the mortality rates of pre-recruits or indirectly exert influence by altering the abundance of forage or predators. Many other aspects of the ecosystem may also alter population levels (Cushing, 1975), however, exact causative mechanisms in most fisheries are seldom known.

Year to year fluctuations in the abundance of exploited species will determine in part the magnitude of annual harvest of those species. But, the relationship will not be completely deterministic, since landings will also be influenced by socio-economic factors (e.g., prices and costs as they affect effort) as well as biological factors unrelated to exploitation (Ricker, 1978). Despite these many complicating factors, significant correlations between various environmental variables and commercial landings of various species have been found in a number of fisheries. Dow (1977), for example, showed that temperature correlates well with the landings of 24 species of finfish, crustacea, and mollusks off the coast of Maine. Sutcliffe (1972) found freshwater input to St. Margaret's Bay to be a good indicator of fisheries production, possibly because of the stimulation of production caused by the nutrients in the runoff water. However, in neither case were the observed relationships demonstrated to help in predicting harvests, nor were the specific mechanisms responsible for the observed relationships rigorously delineated. In contrast, a regression model of brown shrimp landings off North Carolina, using temperature and salinity as independent variables, was found to be a reasonably accurate predictor of future landings (Hunt, et al., 1979). Hunt's model has proven to be a useful management tool for this fishery, helping fishermen to decide how to gear up for the coming season (M. Street, North Carolina Division of Marine Fisheries, personal communication).

Thus, the value of correlative or regression models of fisheries is two-fold: First, significant correlations can serve to guide research into identifying the causes of annual variation in catch; and secondly, if

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
3/8"
PAGE NUMBER
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
EPA Form 2350-6 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

validated, such models may forecast harvest in cases where more detailed deterministic models cannot be developed for lack of information.

To date the relationships between environmental variables and commercial landings in the Maryland portion of Chesapeake Bay have not been investigated in a systematic manner. Since most of the dominant species reproduce in Maryland waters, the influence of environmental variation on harvest of these species may be particularly strong. Thus, we have developed multivariate regressions of the landings of major commercial species, using as predictors those environmental variables considered to have biological significance for the species being examined. Although measures of catch per unit effort (CPUE) would have been preferable as indicators of stock size, adequate effort data were not available. The results provide valuable insight into factors which may contribute to determining the population dynamics of these species and may also prove to be of value in establishing management practices.

Species Addressed and Data Available

Seven dominant species in Maryland landings were selected for analysis. Oysters (*Crassostrea virginica*), hard crab (*Callinectes sapidus*), soft shell clam (*Mya arenaria*), and striped bass (*Morone saxatilis*) were chosen because they are the four species which yield the greatest dollar value to the Maryland economy. Menhaden (*Brevoortia tyranus*) and alewife (*Alosa pseudoharengus* and *A. aestivalis* combined) were selected because they have been dominant in number of pounds harvested. The bluefish (*Pomatomus saltatrix*) was included because its harvest has increased dramatically in recent years, and there was interest in detemrining if this increase might be related to environmental variation.

A 33-year record of annual catch data for 24 commercial species was available from records maintained by the Chesapeake Biological Laboratory and the NOAA Fisheries Statistics Division. These records consist of total Maryland landings (Chesapeake Bay and Atlantic Ocean) for each year. The Chesapeake Bay portion of the harvest heavily dominates the catches of the chosen species (85% or more of total). Because of the difficulty in obtaining sufficient information to separate Bay catch from the State total, the total was assumed to be representative of Chesapeake Bay.

Annual Characterizations of Environmental Data

The environmental variables for which long term records exist are water temperature, air temperature, salinity and precipitation. All four have potential relevance to the levels of commercial harvest. Cross correlative relationships among these variables would be accounted for in the step-wise multivariate regression procedure employed in the analysis (discussed below). Daily recordings of these variables exist for a period exceeding 40 years as taken from the Chesapeake Biological Laboratory pier at the mouth of the Patuxent estuary in Solomons, Maryland. Because this location is central to the Maryland portion of Chesapeake Bay, these data were assumed to be characteristic of conditions in the Bay as a whole. Lacunae in air temperature and precipitation from 1960 onwards were filled by data taken at

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 247)
U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

the nearby Patuxent River Naval Air Test Center in Lexington Park, Maryland.

While catch figures represented the total landings for a season, environmental data existed with much finer temporal resolution. Our goal was to pair each annual catch figure with a value of an environmental property which might be representative of the effect that variable had on the stock during the year the daily readings were accumulated. One straightforward way of characterizing a year is to calculate the annual average of the variable in question. The stock, however, may be more sensitive to shorter-term deviations from this average. In an effort to quantify these deviations we devised four different ways of treating each of the original four time series to yield 26 annual series of environmental data.

The first of these methods, calculating the annual average, has already been mentioned. But the annual mean conveys little information on the cumulative amount of stress or benefit experienced by the populations because of the extreme high or low values of environmental variables. To portray the cumulative effects of these deviations, we defined variables analogous to the degree-days of agricultural science. Here the effect of a variable is assumed to be manifested only when its value goes beyond a certain "bias-level." If, for example, the organism is assumed to be cold stressed when the water temperature falls below 4 °C, then three successive days of 1 °C water temperature will contribute nine degree-days towards the index of cold stress.

For each of the four variables recorded, a high and a low bias level were chosen such that when conditions exceeded these bounds at Solomons, we guessed that there were significant regions throughout the Maryland section of the Bay where fish and shellfish were stressed (or benefited) by the large excursions from the norm. These bias levels are shown in Table 1.

Of course, the fishery might be responding to individual episodes of stress, rather than the yearly cumulative value. We, therefore, elected to measure the lengths of the longest episodes during a year that a variable was beyond the bias values. These episodes were intermediate time-scale phenomena (on the order of one to several weeks), and we wished to avoid contamination from high frequency events. For example, salinity may have remained above 16.2 ppt for all of a 28 day period, save on the 15th day when it dropped to 16.1 ppt. To characterize the episode as 14 days in duration would clearly be erroneous. To avoid such contamination we chose a "gap-interval" for each variable ranging from 3 to 5 days. If the variable did not go beyond the bias level for a duration not exceeding the gap interval, the episode was not terminated, although the days on which the lapse occurred were not tallied in the episode length. Thus, the episode of high salinities mentioned above would be counted as 26 days.

Finally, the possibility remains that the stocks might be acutely affected by short-term, intense stresses. We felt this eventuality would be reflected in the annual extrema of each variable.

These four operations, when applied to the four daily time series, yielded 26 annual time series of interest. (Cumulative and extreme low

EPA Form 2350-4 (4-80)
(PREVIOUSLY EIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE 1980-660-839
TYPING GUIDE SHEET

precipitations are uniformly zero by definition, and provide no information.) These series constituted the possible "predictor vectors" from which those yielding the best multiple regressions would be chosen. The values for the 26 variables calculated for the years 1938-1976 are listed in Ulanowicz, et al. (1980).

Regression Methodology

In most fish stocks, yearclass size is considered to be established by the juvenile stage (Cushing, 1975). For example, oyster spat set (analogous to juvenile stages of finfish) is a good indicator of spawning success (Galtsoff, 1964). Thus, recruitment (and subsequently harvest) is often correlated to those conditions in the past which helped determine the level of juvenile success. In populations where all individuals in a yearclass are recruited into the fishery at the same age, and annual landings consist primarily of a single yearclass, a significant correlation might be obtained when the environmental variable in question was lagged against landings by the number of years equivalent to the age at recruitment.

For most species harvested in Maryland, recruitment is not simultaneous for all members of a yearclass; and landings in one year may consist of members of several or many yearclasses. Thus, environmental characteristics important to establishing yearclass strength may be partially correlated with landings recorded over several years, and vice versa. In order to account for such extended partial recruitment, step-wise regressions were employed, allowing the contribution of a given environmental variable to be assessed by successively lagging that independent variable by annual increments so as to encompass the lifespan of most of the stock being fished.

In the case of species which do not spawn in Maryland and where environmental conditions in the Bay would not influence yearclass size (i.e., menhaden and bluefish), any significant correlations arising would either be the result of how Bay environmental conditions influence the availability of the species to Maryland fishermen, or how Bay conditions might be correlated with critical conditions at the remote spawning site. Oysters and striped bass, being the longer-lived of the species of interest, were regressed against conditions as long ago as nine years in the past. Conditions affecting the remaining species were investigated over the past five years.

The routine used in the search for key factors was the stepwise multiple regression routine BMDP2R written by the Computer and Health Science Department, University of California, Los Angeles, and adapted for execution on the Univac 1108 at the University of Maryland Computer Science Center. Because we had to choose from among as many as 260 possible predictor vectors, it was impractical to determine the best multiple regression in one pass through the program. Successive multiple regressions were, therefore, run for each year of lag. That is, the criterion vector was first run against the 26 environmental series with no lag; then against the same set lagged by one year; by two years, etc. After the appropriate number of lags had been run, the chosen sets of vectors from each year's lag were aggregated into one run to determine the final set of predictor vectors and the multiple regression equation. Each run was terminated when the F-to-enter value of

EPA Form 2360-4 (4-80)
(PREVIOUSLY EPA FORM 337)
U.S. GOVERNMENT PRINTING OFFICE 1980-860-639
TYPING GUIDE SHEET

the next variable to be added to the regression dropped below 4.0, corresponding roughly to a $p < 0.05$ level of significance.

Results and Discussion

To facilitate easy recognition of the environmental variables in the regression equations that are to follow, we adopt a two-letter, one-digit code to designate each of the 260 possible predictor vectors. The first letter will be either A, C, E or X according to whether the processed variable represented an annual average, cumulative deviation, episode or extremum, respectively. The second letter will designate air temperature, water temperature, daily precipitation, or salinity by T, W, P or S, respectively. When it is necessary to distinguish between high or low deviations of these variables, the low values will be designated by writing the second letter in the lower case. Finally, the digit will designate the number of years lag behind the harvest figures. As examples, Cs3 would indicate cumulative low salinity three years in the past, whereas EW2 would denote the longest episode of high water temperatures two years ago.

Regression equations, F and R^2 values of those regressions for each of the seven species are presented in Table 2. Plots of annual landings of the species and the predicted values generated by the regression equations are presented in Figures 1 to 7.

The number of variables entering each regression ranged from 2, in the case of blue crab and menhaden, to 7 in the case of oyster (Table 2). Because of the manner in which these regressions were carried out (260 independent variables entered in a step-wise manner), there exists a strong possibility that spurious variables might enter the regression. In such cases, however, the spurious variable is unlikely to contribute to explaining a large proportion of the total variation. Thus, of the terms in the seven regression equations in Table 2 we focused our interest first upon those individual variables which contributed a major share of the multiple R^2, since these factors would appear to have the greatest likelihood of revealing a causal mechanism. The equation derived for soft clam harvests included one such variable.

In the clam regression, only three environmental variables entered with coefficients that were significantly different from zero, and one (episodes of low water temperature one year before harvest) accounted for 59% of total variation in catch. The other two variables entering were extreme high salinity one year before harvest, which acounted for 15% of the variation, and extreme low water temperature three years before harvest, which accounted for another 13%. Environmental data were available to assess the predictive value of this equation for the year 1977. As can be seen in Figure 1, this projected value has one of the largest deviations from the observed value of any in the graph.

Interpretation of this equation in terms of causality is complicated by the absence of effort data. For example, the effects which the rise in number of licensed clammers (from 3 in 1952 to 100 in 1957 to 200 in 1979 [Richkus et al., 1980]) had on catch cannot be accounted for, and they may

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 357)
U.S. GOVERNMENT PRINTING OFFICE 1980-680-839
TYPING GUIDE SHEET

have been substantial. Still, the strong correlation between extreme low water temperature lagged one year with catch suggests a causal relationship.

In Maryland, soft shell clams spawn in spring and fall (Pfitzenmeyer, 1962). However, the spring set each year is almost totally eradicated because of predation by benthic feeding fish and crabs which migrate onto Maryland clam grounds each spring and leave each fall (Holland et al., 1979). Factors influencing the strength of the fall set (which occurs from October through December) and the ensuing survival of juveniles have not been identified. It appears that these factors are the ones most likely to have the greatest effect on the magnitude of commercial clam landings. Since Maryland is near the southern boundary of the geographical range of soft-shell clams (Manning, 1957), cold water temperatures may, in some unexplained way, enhance the survival of a previous year's set. Furthermore, during some years (i.e., when a dry fall is followed by a cold winter), extreme high salinity and extreme low water temperature could both occur at the same time.

Manning and Dunnington (1956) showed that Maryland clams grow at a rapid rate, achieving legal size (2 inches, 5.1 cm) at an age of 16 to 22 months. Whence clams spawned in the fall of one year would enter the commercial fishery during the spring two years later. Extreme low water temperatures generally occur in January or February of each year and during some years coincide with periods of high salinities. Thus, two of the most significant variables in the regression model could be exerting an effect on juvenile clams from set to the age of 6 to 7 months, when they are approximately 0.5 cm (0.2 inches) in size. Low water temperature may delay movement of predators into Maryland waters, permitting juvenile clams to grow to a less vulnerable size. High salinities during the juvenile life stages could also favor growth and rapid maturation of clams.

The other significant variable in the regression is difficult to interpret causally. Extreme temperatures 3 years after set would have little likelihood of influencing landings in any given year, since soft-shell clams in Maryland live only about 3 years (Manning, 1957). Three year old clams probably contribute little to total landings. Also, the regression coefficient is negative, contradicting the positive correlation with extreme low temperature one year ago.

The blue crab regression, although it explains only 36% of variation in landings, suggests a possible causal relationship. Both variables entering the regression (Table 2) have 0 lag and negative coefficients, and they both reflect effects of low water temperature. Such cold temperatures occur in January or February each year and can cause mortality of crabs overwintering in Maryland waters (e.g., Krantz, 1977). The regressions suggest that winter kill may have a significant effect on Maryland blue crab harvests.

The remaining five regressions are composed of variables which are less readily explained. The two terms entering the menhaden regression have 4 year lags (Table 2), yet menhaden which make up Maryland landings are of ages 2 and 3, with almost no 4 year old fish taken (J. Merriner, personal communication). Thus, any causal mechanism suggested by the regression would

EPA Form 2360-4 (4-80)
TYPING GUIDE SHEET

have to be a second generation response, except that menhaden do not become sexually mature until ages 3 or 4. Similarly forty-one of the total sixty-eight percent of the variation in alewife catch is explained by the negative correlation with episodes of drought three years in the past.

Both species included in landings as alewives (*A. pseudoharengus* and *A. aestivalis*) are anadromous, tributary spawners in Maryland (Hildebrand and Schroeder, 1928). Thus, poor spawning success could readily be related to low freshwater runoff caused by low precipitation. However, the age of first spawning of these species is from 3 to 5 years, with the majority spawning at 4 or 5 (Davis et al., 1971). The regression suggests the possibility that recruitment in Maryland occurs at a younger age, but data on the age distribution of the catch are unavailable to confirm or refute this suggestion. The other variables entering the alewife regression (Table 2) all have lags of 1 or 2 years. Since fish taken in a given year would have been present in the Atlantic Ocean 1 and 2 years before being harvested, these correlations are difficult to explain in a causal manner.

Juvenile bluefish use Chesapeake Bay as a nursery area and there exists the possibility that a distinct Chesapeake Bay stock of bluefish exists (Kendall and Walford, 1979). Bluefish, being a marine species, are generally not found in low salinity waters, and their distributions can be well defined by salinity patterns (Lippson et al., 1980). Thus, the precipitation variables entering the regression (Table 2) may reflect diminished nursery habitat caused by high precipitation, resulting in a decline of harvestable fish in future years. However, age composition of Maryland bluefish catch is unknown, and the particular lags in the precicpitation variables in the regression are not readily explained.

The seven variables in the oyster regression explain 82% of the total variance. Thirty-one percent of the variance is attributed to the episodes of low water temperature nine years ago. Ulanowicz et al. (1980) also reported the strong influence of factors nine years past, presumably because of some intrinsic environmental cycle. Probably the best qualitative interpretation of the various terms would be that spat setting success is abetted by low temperatures and high salinities, whereas the growth of the adults is fostered by periods of warm summer temperatures.

Eighty-two percent of the variation in catch of striped bass could be quantified by six variables. The correlations with temperature appear highly contradictory at first glance, but actually agree with current hypotheses. The first two terms (52% variance explained) show a favorable correlation with cold *air* temperatures over a season. Cold seasons are conducive to greater amounts of ice formation along river edges. The scouring from ice floes contributes high quality detritus to the riverine system to supplement the food source for zooplankton, in turn providing the larvae with abundant food (Heinle et al., 1976). The delivery of this detrital material to the tidal estuarine nursery area is facilitated by higher flow rates (as reflected in the positive correlation with episodes of low salinity). Boynton et al. (1976) have previously remarked that year class success correlates jointly with cold winters and high runoff. The organisms themselves, however, do not tolerate low *water* temperatures well (Davis,

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
TYPING GUIDE SHEET

1973) — whence the negative correlation with cold water temperatures, as evidenced by the last three terms (21% cumulative variance explained).

Concluding Remarks

The results of the analyses presented here are provocative but should be viewed with caution. The fact that substantial portions of the variability in landings of all the species considered can be explained by various combinations of environmental variables suggest the important role which environmental conditions play in determining stock size. However, our inability to interpret many of these relationships in a causal manner reflects both a lack of knowledge of mechanisms influencing fish population dynamics as well as an unfamiliarity with the auto and cross correlative relationships between the variables introduced into the regression process. (Because the procedure employed was step-wise, true causal variables may have been displaced in the regressions by spurious variables which by chance were closely correlated. No detailed analysis of the independent variable data sets was performed to address this issue. More analyses would be required to fully account for this possibility.)

Despite these limitations, the analyses appear to have been fruitful, particularly in the case of the soft clam. As for the other species, the value of the models will be determined when sufficient data are available to assess their predictive value for future landings. Only then can it be ascertained whether the initial derivation was spurious or reflected some unknown causal relationship between environmental variation and stock dynamics. Meanwhile, the terms appearing in the regressions may engender new research projects into the mechanisms determining the sizes of these important fisheries stocks.

Acknowledgments

This work is a result of research sponsored in part by the NOAA Office of Sea Grant, Department of Commerce, under grant no. 04-7-158-44016. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon. Mr. Ali's internship at CBL was jointly sponsored by the Directorate of Fisheries, Government of Bangladesh and the World Bank. Ms. Vivian was supported by the Environmental Protection Agency's Chesapeake Bay Program, Eutrophication Project, grant no. Sub R806189010. Dr. Martin Wiley provided comments helpful in revising the manuscript. The Computer Science Center of the University of Maryland donated some of the computer time used in this project.

Literature Cited

Boynton, W. R., E. M. Setzler, K. V. Wood, H. H. Zion, M. Homer and J. A. Mihursky
1976. Potomac River fisheries program ichthyoplankton and juvenile investigations. Ref. No. 77-169CBL, Center for Environmental and Estuarine Studies, Solomons, Md.

EPA Form 2350-4 (4-80)
(PREVIOUSLY DIN. EPA FORM 237)
TYPING GUIDE SHEET

Cushing, D. H.
1975. Marine Ecology and Fisheries. Cambridge University Press, New York.

Davis, J., J. V. Merriner, W. J. Hoagman, R. H. St. Pierre and W. L. Wilson
1971. Annual Progress Report, Anadromous Fish Project. Proj. No. Va. AFC7-1. Virginia Institute of Marine Science, Gloucester Point, Va.

Davis, W. D.
1973. The effect of total dissolved solids, temperature and pH on the survival of immature striped bass. Prog. Fish-Cult. 35(3):157-160.

Dow, R. L.
1977. Effects of climatic cycles on the relative abundance and availability of commercial marine and estuarine species. J. Cons. int. Explor. Mer. 37:274-280.

Galtsoff, P. S.
1964. The American oyster, _Crassostrea virginica_ Gmelin. Fish. Bull. 64:1-480.

Heinle, D. R., D. A. Flemer and J. F. Ustach
1976. Contributions of tidal marshlands to Mid-Atlantic estuarine food chains. Pages 309-320 _in_ M. L. Wiley, ed., Estuarine Processes, Vol. II, Academic Press, New York.

Hildebrand, S. F. and W. C. Schroeder.
1928. Fishes of the Chesapeake Bay. U.S. Bur. Fish. Bull. Val. 53(1).

Holland, A. F., N. K. Mountford, M. Hiegel, D. Cargo and J. A. Mihursky.
1979. Results of benthic studies at Calvert Cliffs. Final Report to Maryland Power Plant Siting Program. Ref. No. PPSP-MP-28, Martin Marietta Laboratories, Baltimore, Md.

Hunt, J. H., R. J. Carroll, V. Chinchilli and D. Frankenburg.
1979. Relationship between environmental factors and brown shrimp production in Pamlico Sound, North Carolina. Completion Report for Project 2-315-R, North Carolina Department of Natural Rsources, Moorehead City, N.C.

Kendall, A. W. and L. A. Walford.
1979. Sources and distributions of bluefish, _Pomatomus saltatrix_, larvae and juveniles off the east coast of the United States. Fish. Bull. 77(1):213-227.

Krantz, G. E.
1977. Bay Ice Team Effort. Ref. No. 77-112HPEL. Center for Environmental and Estuarine Studies, Cambridge, Md.

EPA Form 2350-4 (4-80)
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

Lippson, A. J., M. S. Haire, A. F. Holland, F. Jacobs, J. Jensen, R. L. Moran-Johnson, T. T. Polgar, and W. A. Richkus.
1980. Environmental Atlas of the Potomac Estuary. Johns Hopkins University Press, Baltimore, Md.

Manning, J. H.
1957. The Maryland soft-shell clam industry. Study Report 2. Maryland Department of Research and Education, Solomons, Md.

Manning, J. H. and E. A. Dunnington.
1956. The Maryland Soft Shell Clam Fishery: A preliminary investigation report. Proc. Nat. Shellfish Assoc. 46:100-110.

Pfitzenmeyer, H. T.
1962. Period of spawning and setting of the soft shelled clam, *Mya arenaria*, at Solomons. Chesapeake Sci. 3(2):114-120.

Richkus, W. A., J. K. Summers, T. T. Polgar and A. F. Holland.
1980. A review and evaluation of fisheries stock management models. Martin Marietta Laboratories, Baltimore, Md.

Ricker, W. E.
1978. Computation and Interpretation of Biological Statistics of Fish Populations. Bulletin 191, Department of the Environment Fisheries and Marine Service, Ottawa.

Sissenwine, M. P.
1978. Is MSY an adequate foundation for optimum yield? Fisheries 3(6):22-42.

Sutcliffe, W. H. Jr.
1972. Some relations of land drainage, nutrients, particulate material, and fish catch in two eastern Canadian bays. J. Fish. Res. Board Can. 29:357-362.

Ulanowicz, R. E., W. C. Caplins and E. A. Dunnington
1980. The forecasting of oyster harvest in Central Chesapeake Bay. Estuarine and Coastal Marine Science (in press).

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
☆ U.S. GOVERNMENT PRINTING OFFICE 1980-660-820
TYPING GUIDE SHEET

Table 1. Parameters used in calculating cumulative variables and episodes.

Variable	High Bias	Low Bias
Salinity	16.2 ^{o}/oo	10.5 ^{o}/oo
Water Temperature	26.5 ^{o}C	4 ^{o}C
Air Temperature	30 ^{o}C	0 ^{o}C
Precipitation	3 cm/day*	0 cm/day

*This value becomes 0.01 cm/day in calculating rain episodes, i.e., any day it rains is counted.

Table 2. Multivariate regression models of landings (in metric tons) of designated species; see text for code to predictor variables.

Species	Regression	Multiple R^2	F	df
Soft clam (*Mya arenaria*)	$H_s = -4878 + 34.22Ew1 + 310XS1 - 346Xw3$	0.86	44.4	21
Blue crab (*Callinectes sapidus*)	$H_c = 15320 - 44.58Cw0 - 1403Xw0$	0.36	8.3	29
Bluefish (*Pomatomus saltatrix*)	$\log H_b = 1.927 - 0.0545EP3 - 0.0893XP9 + 0.0095EW7 + 0.0095Ep6$	0.77	21.1	25
Alewife (*Alosa aestivalis* and *A. pseudoharengus*)	$H_a = -4208 - 22.84Ep3 + 114.9Xt2 + 225.1XW2 + 8.12CW1$	0.68	14.7	28
Menhaden (*Brevoortia tyrannus*)	$\log H_m = 3.193 - 0.065CT4 + 0.0155Ep4$	0.56	17.5	28
Striped Bass (*Morone saxatilis*)	$H_b = 3022 - 351.7AT3 + 2.055Ct1 + 3.152Es9 + 240.1AW9 - 232.1Xw2 - 4.50Cw2$	0.82	17.6	23
Oyster (*Crassostrea virginica*)	$H_o = -955.3 + 18.18Ew1 + 28.42EW1 + 26.11EW2 - 9.45Cw2 + 332.2XS6 - 9.73Es5$	0.82	14.3	22

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE
TYPING GUIDE SHEET

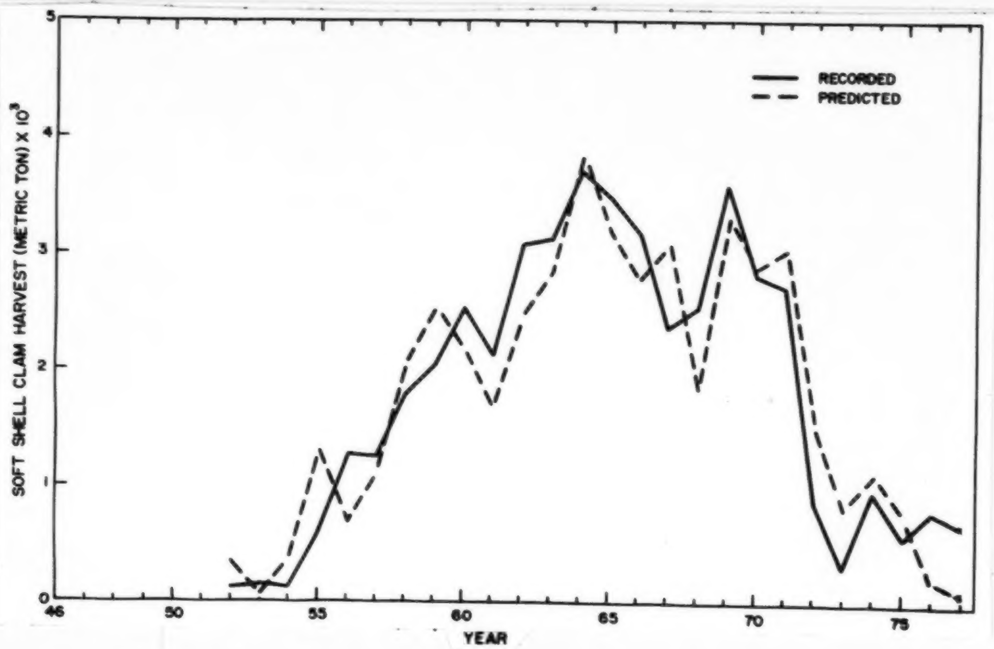


Fig. 1. Maryland soft clam landings from 1952 to 1977 (solid line) and landings predicted using the regression model (Table 2). Landings for 1977 did not enter into the derivation of the model.

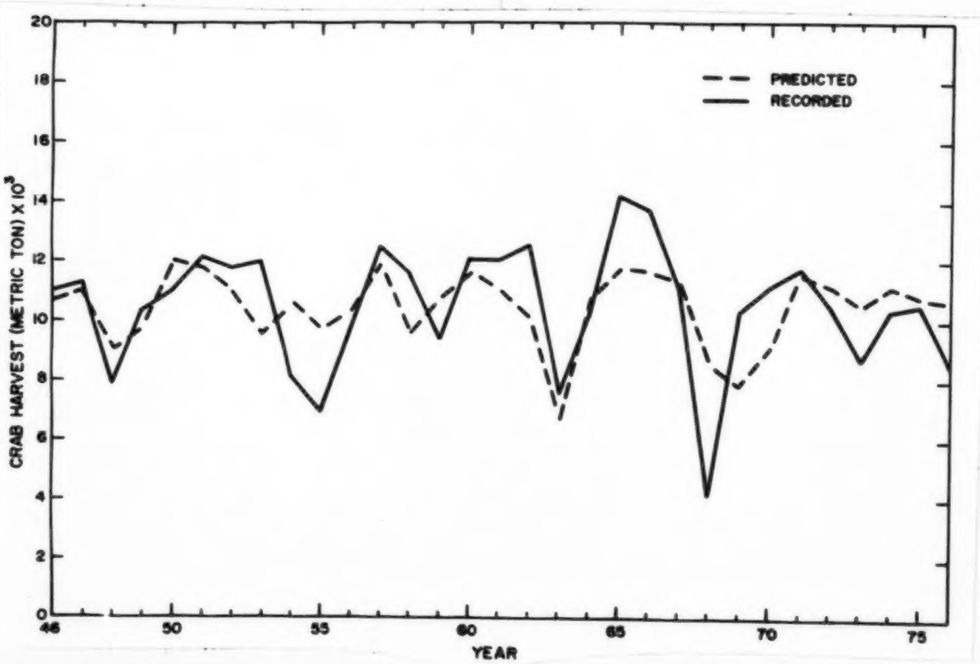


Fig. 2. Observed and forecasted values for hard crab catch, 1945 to 1976.

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE
BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"
PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 287)
U.S. GOVERNMENT PRINTING OFFICE: 1980-660-639
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

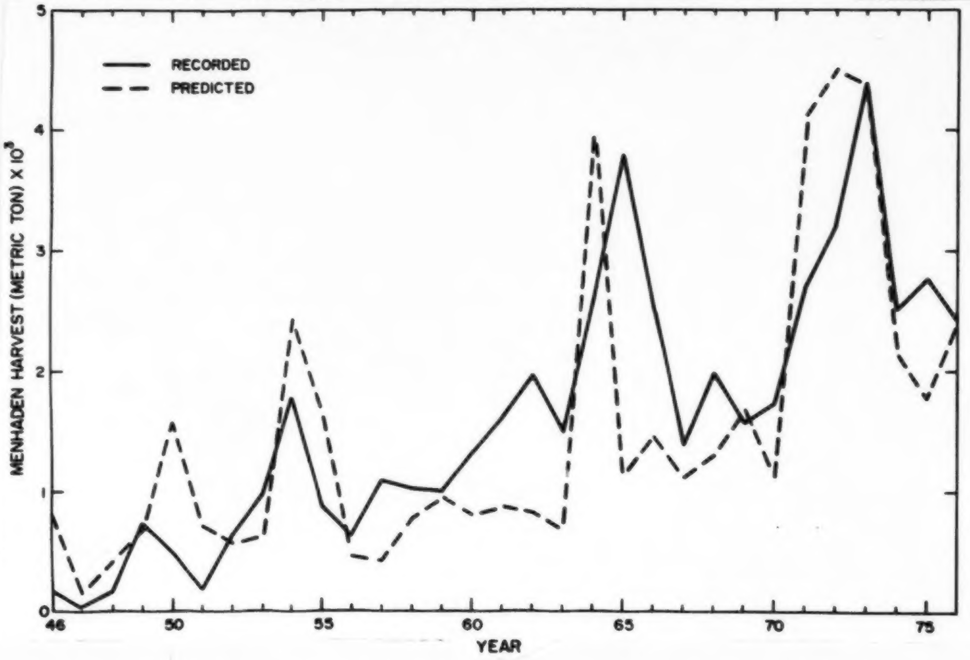


Fig. 3. Actual and predicted catches of menhaden, 1946 to 1976.

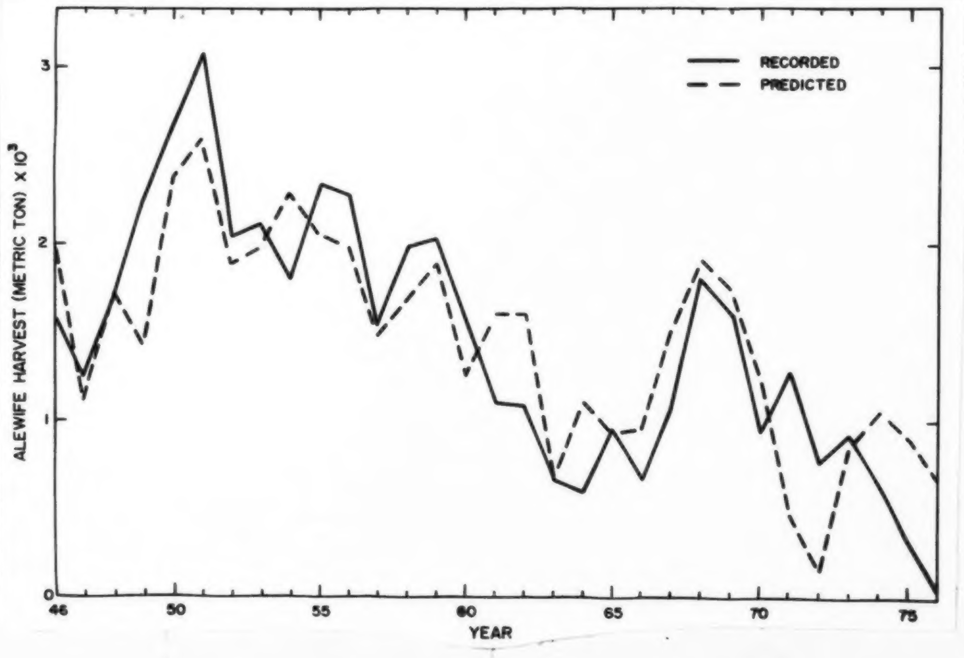


Fig. 4. Annual landings of alewife, 1944 to 1976, as computed with predicted values.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA, OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 387)
© U.S. GOVERNMENT PRINTING OFFICE 1980-660-639
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD: BEGIN SECTIONS HERE

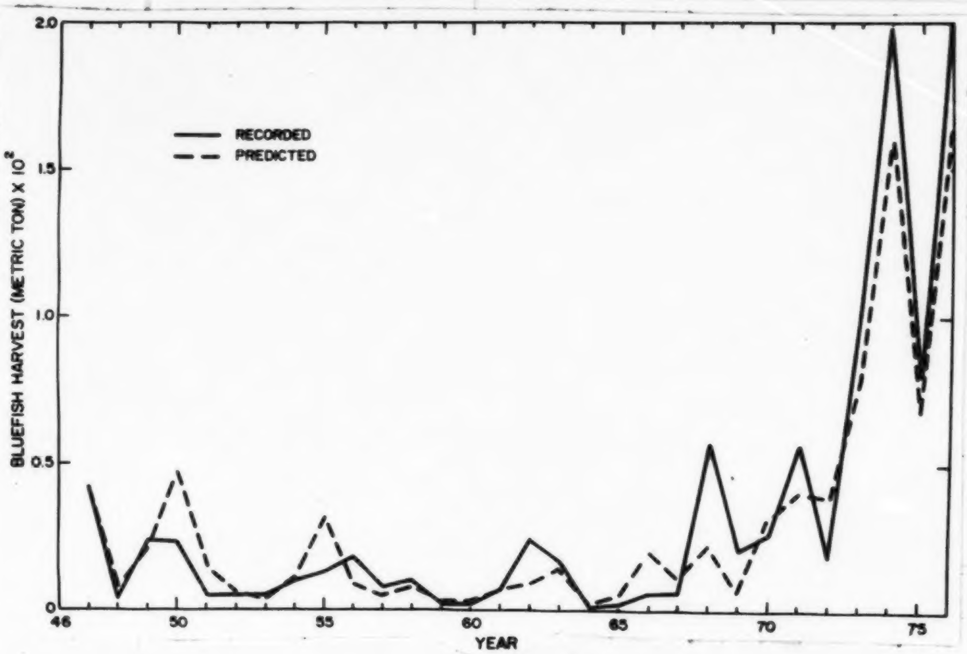


Fig. 5. Predicted and recorded weights of bluefish landings, 1947 to 1976.

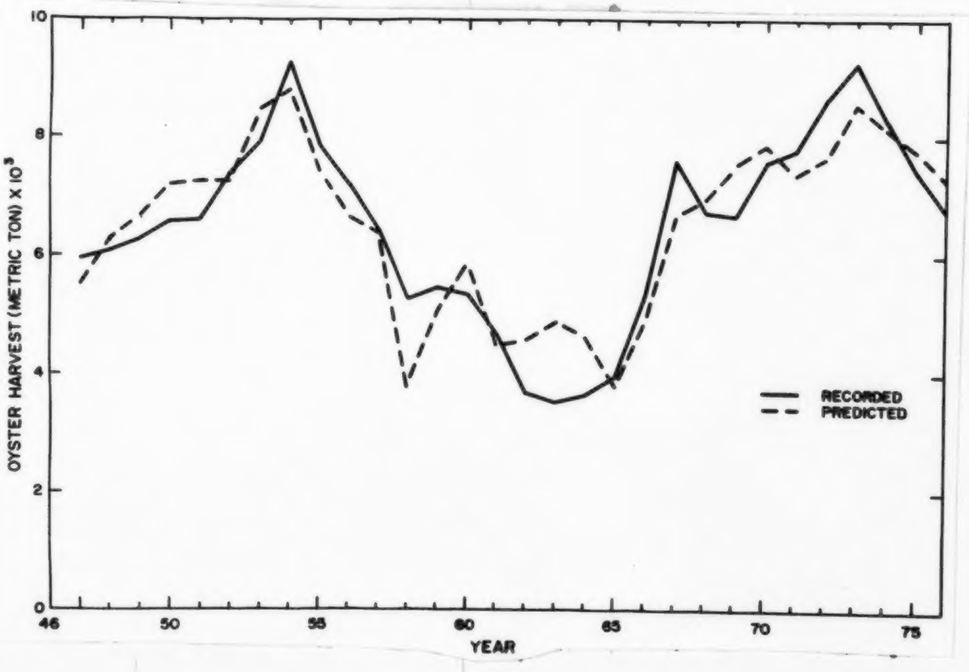


Fig. 6. Comparison of recorded and predicted oyster catch for the years 1947 to 1976.

BEGIN LAST LINE OF TEXT
BOTTOM OF IMAGE AREA; OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS
3/8"

PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 297)
☆ U.S. GOVERNMENT PRINTING OFFICE: 1980-660-620
TYPING GUIDE SHEET

BEGIN FIRST LINE OF TEXT HERE
CENTER OF PAGE
TOP OF IMAGE AREA
DROPPED HEAD; BEGIN SECTIONS HERE

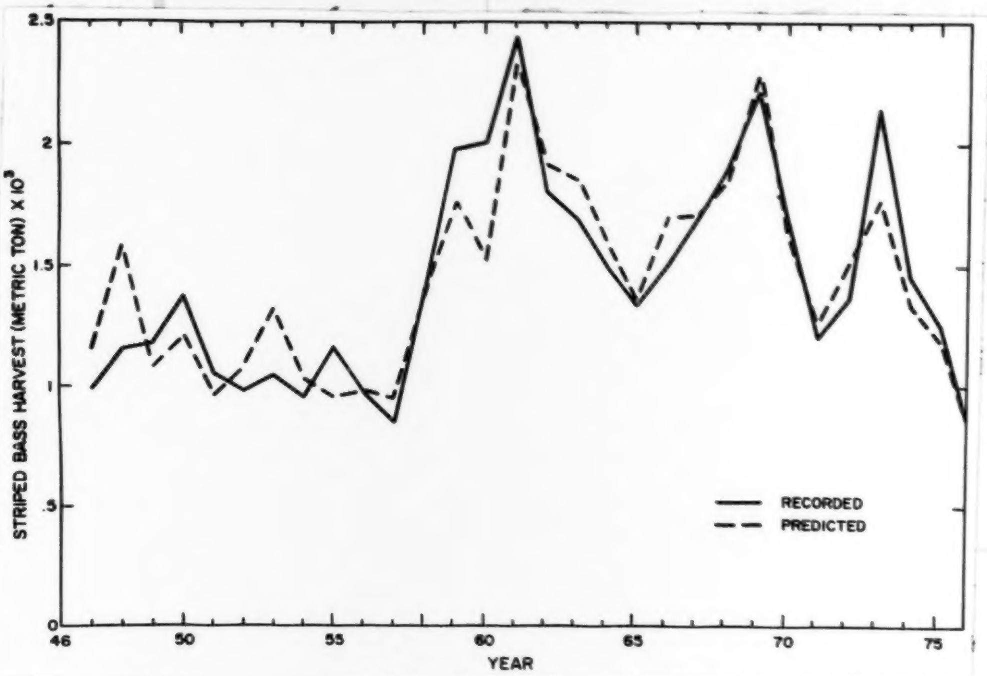


Fig. 7. Predicted and tabulated landings of striped bass from 1944 to 1976.

BEGIN LAST LINE OF TEXT
3/8"
BOTTOM OF IMAGE AREA OUTSIDE DIMENSION FOR TABLES AND ILLUSTRATIONS

PAGE NUMBER
EPA Form 2350-4 (4-80)
(PREVIOUSLY CIN. EPA FORM 257)
U.S. GOVERNMENT PRINTING OFFICE
TYPING GUIDE SHEET